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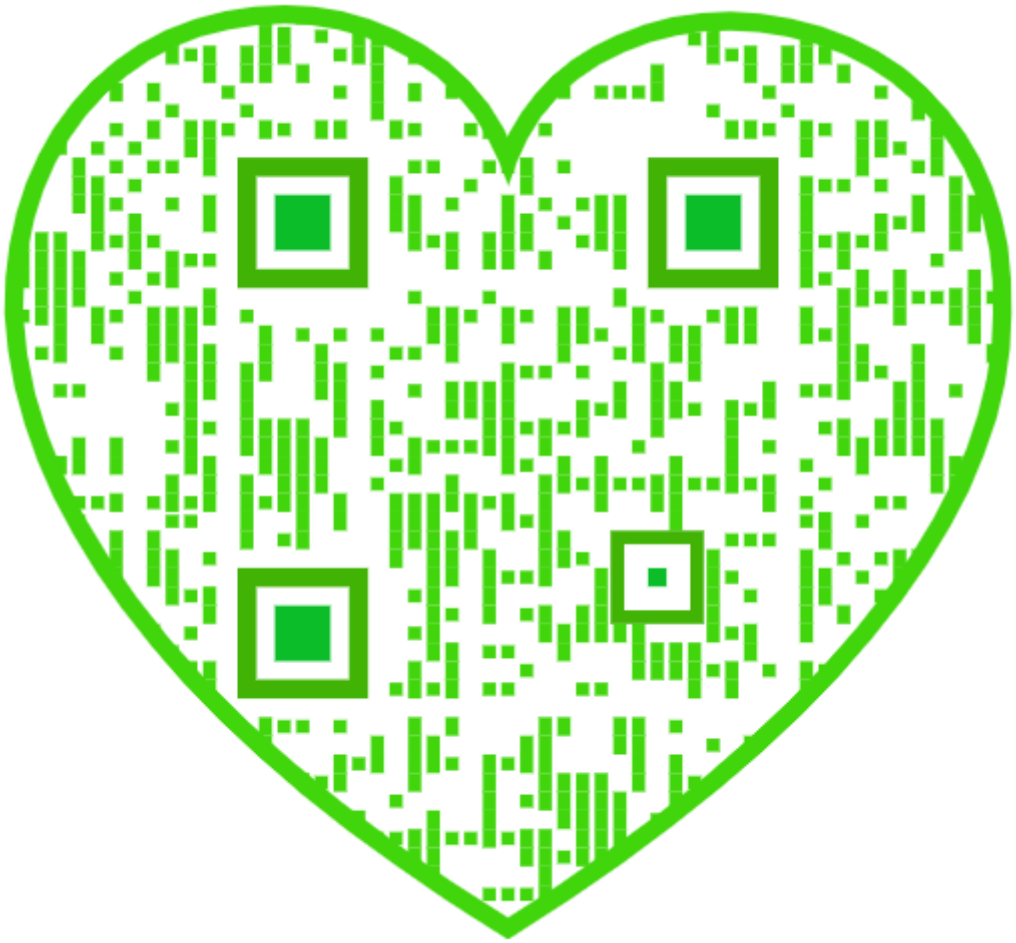

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SURVEYING

FOR

BEGINNERS

J. B. DAVIS
1895-1909

UNIV. OF CALIFORNIA
SOUTHERN BRANCH

ANN ARBOR, MICHIGAN
1909

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UNIV. OF CALIFORNIA
SOUTHERN BRANCH

The Ann Arbor Press

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LIST OF WORK

I. Reading Verniers.

II. Measuring with Steel Tapes.
Survey of a triangle.
Measuring the same distance eight times.

III. Handling Instruments.
Transit. Line Staff.
Level.
Leveling Rod.

IV. Survey of a triangle with a transit.
Twenty rod readings on the same B. M.

V. Reading Angles. Closing the horizon.
Peg Levels. Short circuit.

VI. Traverse Survey. Field with seven sides.
Peg Levels. Long circuit.

VII. Traverse Survey. Computing and platting.
Profile Leveling.

VIII. Profile and Grade Line.
Staking out a grade.

IX. Straight Line.
Staking out a building.

OUTFIT. NOTICE.

1. Outfit required.

For each person:

Reprints and pamphlets.

Direction of a Line.	Recommended.
Leveling and Earthwork.	
Town, City, and Village Plats.	Recommended.
Transit. Adjustments and Tests.	Recommended.
Traverse Surveying.	

Field Note Book, like sample.

Lead Pencil, Faber, No. 5, red hexagon.

Eraser, typewriter, small.

Cross ruled paper, for platting.

For each party:

Wire spikes, 6″.	12
Wire lath nails, 3d fine.	¼ lb.

Boy's axe, sharp.

Marking crayon.

2. Notice.

Once telling is enough.

Parties consist of two, or four, persons, ordinarily.

Time for each duty will be limited.

Shortcomings to be made up outside of class time, and without delay.

Do the work in the order in which it is listed.

Every person must "Figure."

Put all computations in field note book, with notes.

No loose papers allowed.

Do not come here with parts of the notes of a piece of work in different books. Every note book must contain them all.

Present all records, maps, and drawings, and get O.K. or make them over till given O.K.

Late comers make up all back work within three weeks, or drop out.

Instruments, apparatus, and tools, are issued on the check system. Each one get five checks from the instructor, for which a charge of fifty cents is made. The money will be returned at the end of the semester upon the return of the checks. A check is left for each article issued. The checks are returned upon the return of the articles in the same condition as when issued.

No playing with tools, or apparatus.

Pay for all losses or breakages.

Report, at once, all losses, breakages, or defects, to have them made good in time for the next work.

Write up lecture notes with neat diagrams for same, using water-proof ink.

When a word, or a sign, is not understood, look it up then and there, in a dictionary, or text book, or inquire of a teacher at the next opportunity.

We do not teach what may be read in a book, without aid.

Learn how to do things by doing them,—same as baseball is learned. "Practice makes perfect."

Recitations are the examination, except a written examination upon the subjects of the field work.

Review Plane Geometry and Plane Trigonometry.

Surveying is learned by study, by work, and by practice,—not by merely staying 'round where surveyors, books, and instruments are.

"It is better not to know so many things than it is to know so many things that are not so."

"You can find eighteen men who can tell how to do a thing where you can find one who can do it."

—*Josh Billings.*

3. Not so.

When you "See it," you know it.

Something will prove useful which is written down carefully and specifically, with order, decorum, and diagrams, in a note-book, and then laid aside and forgotten.

You can "laze" around at the beginning of the semester and make up for it by cramming towards the end.

One can get along here, or elsewhere, as an engineer, without being able to write plainly, make neat figures, and use with facility, some style of plain lettering.

A surveyor can "establish" a landmark or a boundary.

A "true" meridan,—a "magnetic" meridan.

The "declination" of the magnetic needle.

"Printing" a statement in a book *makes* it true.

4. An engineer should be able to

Measure a distance.
Measure an angle.
Keep notes.
Run a traverse.
Run a straight line.
Take levels.
Make computations.
Make maps and drawings.
Write a report.
Take care of instruments.
Use a needle compass, some.
Lay out a curve.
Oversee equipment.

5. A survey consists of

The field work.
The field notes.
The calculations.
The permanent record.

Unless what each of these items implies is completed in a thorough and workmanlike manner, the survey will be imperfect, and usually inadequate. Such surveys commonly prove to be both unsatisfactory and expensive.

6. The Field Work comprises many kinds of operations and labor.

1. Running lines, straight or curved, and marking their location with stakes, or otherwise.

2. Measuring distances, with a chain, tape, stadia, or other device.
3. Finding the direction of a line.
4. Measuring angles, with a divided circle, a steel tape, or other means.
5. Placing, and constructing, monuments, such as landmarks and station marks.
6. Getting differences of elevation, or running levels, as it is called.
7. Making bench marks for the levels.
8. Digging for old landmarks.
9. Sounding.
10. Making borings for showing materials.
11. Gauging of streams.
12. Building stations for triangulation.
13. Making astronomical observations.

This list is not exhaustive, only illustrative.

7. **The Field Notes** are made in the field. They are a plain, orderly, neat, and complete, record of the field work, and attendant conditions, circumstances, and facts, made according to the directions below.

1. Mark name and number of party neatly and plainly, at top right hand side of first outside cover of note-book.
2. Number leaves of note-book, if not numbered.
3. Select a brief and comprehensive title. Enter this title at top of every new page to be used for notes.
4. Enter the date on every page of notes, and at beginning of notes of each day's work.
5. Note instruments used, and any special tools, or apparatus, on each leaf of note book.
6. Record the place where work is done.
7. Write an explanation of the object of the work, if not apparent from the title or the notes themselves.
8. Write the name, position, and duty, of every person who does any part of the field work.

9. Make a plain, full, complete, orderly, and unmistakable, record of every thing done, every fact ascertained, and the evidence and witnesses therefor. Record what is seen, without alteration, computation, or modification. Set down every act, or fact, at once. Trust nothing whatever to memory.

10. At the bottom of each page of notes place the signature of the recorder,—also at the end of the record of each day's work.

11. When the notes of any work are in different parts of the book, write, at the beginning of the record at every place in the book, a reference to the place where the preceeding notes ended, and at the end of every record a note of the place where the record is continued. The same applies to records contained in different books.

12. When the note book is filled, enter a title on the outside of the front cover, with the dates of beginning and ending the records therein.

13. Make, and enter, an index in the book, if needed.

8. **The Calculations** are generally made in the office, though many minor ones are made in the field, especially in land and railroad surveying and in staking out works. When made in the field they should be spread on the pages of the field note book in an orderly manner, as part of the field notes. In any case, if the calculations are relatively brief, they should be entered in the field note book immediately following, or, by cross references, immediately in connection with, the field records and the results made a part of those records. More extensive and elaborate calculations require a system adapted to the work, but, in general, the figures and results should be carefully preserved in a well kept record. What is known in the trade as the Standard Figuring Book may be useful. The page is 9″ x 12″ cross ruled in ¼″ squares. The calculations must be completed in order to obtain the results and fulfill the purposes for which the survey was made.

9. The Permanent Record preserves the results of the previous labors as well as completes the survey. It may consist of only a field note book, suitably reviewed, indexed and marked; or there may be elaborate reports accompanied by fine maps, with detailed plans, and estimates. It all depends upon the kind, extent, and purpose of the survey.

Here should be read Appendix "G" of Johnson's Surveying, this being Professor Raymond's paper on what constitutes a survey.

10. Maps and Plats should contain

1. Map, or plat, properly drawn and lettered,—not a scrawl, or fragment.
2. Border.
3. Title.
4. Scale. A linear scale, if to be reproduced.
5. Direction mark. Meridian and azimuth.
6. Explanations, if needed.
7. Party who made the survey.
8. Draftsman's name.
9. Dates. Of survey. Of map.
10. Designations of stations, land marks, and notable points of survey.
11. Line of reference.
12. Dimensions. All in one unit ordinarily. Distances. Depths. Sizes. Elevations.
13. Angles. Azimuths. Bearings.
14. Names of objects. Such are, rivers, streets, places, land owners, buildings.
15. Sketches. Illustrations.
16. Results. Such are, areas, amounts, quantities, volumes.
17. Authority for making. Often may be part of title.
18. Location; including state, or country; district or county; township, village, or city; and name of locality; any, or all, of these, or similar terms, that may be necessary to designate unmistakably the position of the survey on the ground. Often may be included in sub title.

19. If on more than one sheet, put on each the whole number of sheets and its own number, thus,....sheets. Sheet No.....

The sheets should be made to be read from the bottom and right hand side.

A standard size for sheets should be used on any survey of considerable extent wherever it is practicable to employ such.

Things shown should be given proper relative prominence,—not one of them, as the title, or draftsman's name, overshadowing all the rest. This is the primary requisite of good map making. Consult; good atlases, such as the Century Atlas; U. S. Charts; Reports of U. S. Coast and Geodetic Survey; Maps of U. S. Geological Survey; published drawings; and books for the guidance of draftsmen. Note the breadths of lines used, and measure, and compare, the heights of letters.

Maps and plats should plainly show:

1. What they were made for.
2. What they represent.
3. Where the things represented are.
4. When they were made.
5. Where they were made.
6. Who they were made by.
7. What the authority was for making them, if made by the order of some official, under any Act of Congress, statute, ordinance, or order of a court.

11. **Reports** should follow the same general lines as the field notes and maps. Consult the reports of notable surveys, such as that of the Deep Water Ways Commission, or the reports of individual engineers of standing relative to proposed works, as that of Mr. Joseph Ripley, U. S. Ass't Eng'r on the connection of Birmingham, Ala., with the Black Warrior River, by canal, which may be found in the Reports of the Chief of Engineers U. S. A.

I. READING VERNIERS.

INFORMATION.

12. **A vernier,** in general, is a device for indicating certain fractional parts of one of the equal spaces, or divisions of a graduated line. The graduated line may be straight, as on a scale, or a leveling rod, or it may be curved, as on the plate of a transit. The vernier itself is a short scale of equal parts, straight or curved to fit the graduated line to which it applies.

See what is the value of a space on the scale, or circle, to which the vernier applies.

Place the vernier so two marks on it match, or are in exact line with, two marks on the scale or circle. Count the spaces on the vernier between these two marks.

Divide the value of a space on the scale, or circle, by this number.

The quotient will be the least reading of the vernier.

13. **To read a vernier,** see where the zero line, or index, of the vernier points. If this index, or line, matches a line on the scale, or circle, that line on the scale, or circle, will show the reading of the circle, or scale, at once, without the aid of the vernier. If the index of the vernier does not match a line on the scale, or circle, look along the scale, or circle, in the direction in which the reading is to be taken, and note the reading of the scale, or circle, shown by the line next preceding the index of the vernier. Look along the vernier and find a line on it which matches a line on the scale, or circle. Note the number of divisions of the vernier between this line and its index or zero line. Multiply this number by the least reading of the vernier to get that part of the whole reading which is given by the vernier. This multiplication is commonly done un-

consciously by means of the mechanical aids supplied for reading the vernier. Add, or annex, the vernier reading to the scale, or circle, reading, previously noted, to get the full reading, up to the index of the vernier.

When looking for the mark on the vernier which matches a mark on the scale, or circle, observe one or two marks on the vernier each way from the one supposed to match with a mark on the scale, or circle. These marks should mismatch the marks on the scale, or circle, equal amounts, in opposite directions, when at equal distances from the mark which is supposed to match precisely. Thus make sure which mark on the vernier it is that really matches precisely with a mark on the scale, or circle. When no mark on the vernier really matches precisely with a mark on the scale, or circle, the actual reading of the vernier may be obtained to one-half, or even one-third, of its least reading, by observing the marks on the vernier in the manner described.

Useful ways of applying and reading verniers are to be learned by experience.

I. READING VERNIERS.

PRACTICE.

14. Directions.

Ascertain and record the least reading of each vernier.
Take and properly record twenty full readings of each.
See 50 for samples of vernier readings.
Total number of all vernier readings is 180.
Should be taken up in the order in which they are named.
Leveling Rods.
Boston. New York. Troy. Philadelphia.
Short rod and long rod,—ten readings of each.
Railroad Compass, or Transits 1884, or 1885, or the like.
Transit 1382, or 1383, or 1384, or the like.
Plate. Vertical Circle.
Transit 4838, or the like.
Plate. Vertical Circle.

II. MEASURING WITH STEEL TAPES.

INFORMATION.

15. **A steel tape measuring set** includes the articles named below:

A one hundred feet steel tape, with but a few marks on it, and its reel.

Two handles for the one hundred feet steel tape,—split sticks, 3″ long, will do.

A fifty feet steel tape, divided to hundredths of a foot, in its case.

Two brass 1 lb. plump bobs, with strings.

Eleven 6″ wire spikes.

An axe.

Line staves may be needed for ranging lines.

Find where the end marks for distance are on both tapes. This must be done before correct measurements can be made. The ends of the 100 ft. tape often do not indicate its length, there being an extra 1.′25 to 1.′50 of steel ribbon at each end. The zero of the 50 ft. tape may be found by turning the end of the tape back; matching the 1 ft. mark to some other foot mark on the tape; smoothing out the loose end beside the tape; and noticing on it, exactly where the next foot mark fits, at, or near, the free end.

Keep the steel tapes wound up,—as much of the time as possible, and get the work done.

Wind any steel tape so the figures are within the coils, and with the zero at the free end.

The zero end of a tape goes ahead, when measuring.

The 100 ft. tape is taken off of its reel and a handle slipped on each end of it when marking a tape length. The handle at the forward, or zero, end, should not slip off from the tape of itself. The handle at the rear, or 100 ft., end, should slip off very easily, because it should be taken off when the tape is drawn forward.

If the 100 ft. tape has been mended, test the spaces between the marks on it by comparison with a standard, or with corresponding spaces marked by small wire nails in stakes driven in the ground till firm, and having their tops all at nearly the same elevation. The spaces between the wire nails may be laid off with the 50 ft. tape.

Make a table of the correct total distances from the zero of the 100 ft. tape to each of the marks on it. Use this table in recording measurements with this 100 ft. tape.

Two men make the measurements, one at each end of the tape.

Call the one at the zero end the Leader, as he goes ahead, and the other the Follower.

The follower is responsible for the correctness of all measurements.

The leader must watch and aid in every way he can to make correct measurements. Errors are not tolerated.

In following a line both should keep the line by referring its range to some object beyond the other. While measuring, both should be on the watch for other objects on the range of the line, as usually, owing to the lay of the ground, the same object cannot be used to range by for any considerable distance. Both men should know the exact range of the line at all times, if possible. When starting, the follower puts the leader exactly in line, whereupon the leader selects an object on the range and beyond the place the measurement starts from. As they move forward the follower ordinarily directs the leader on to the line as each tape length is marked, but the leader should carefully observe whether, by his own marks, he is on the line, or not.

Before beginning a measurement, the follower counts the spikes, and lays one beside the mark from which the measurement is to proceed. He hands the others to the leader and says "Ten!" The leader counts them and says "Ten!" In this way they make sure of starting with the right number of spikes, and with ten of them in the hands of the leader..

Draw out the tape the full length with the zero end ahead, and about on line.

Leader take the zero end in hand, and put on his handle.

Follower slip his handle on the 100 ft. end, and bring the 100 ft. mark about to the mark to be measured from.

Follower directs leader accurately into line, and shows the leader the mark from which the measurement is to proceed.

Leader takes the range of the line carefully, and finds some object, if possible, on the range beyond the follower. If such an object cannot be found leave a picket just back of the mark to be measured from, set exactly on the range of the line. A picket may be a stick of suitable length.

Leader draws up the tape ready to measure.

Follower holds 100 ft. mark exactly to the mark to be measured from, and directs the leader to hold the zero end of the tape exactly in line.

Leader pulls 15 or 20 lbs. on the tape.

Follower looks once more at the 100 ft. mark on the tape and sees that it is exactly at the mark to be measured from and that the zero end of the tape is on line.

When both men are satisfied that the conditions are favorable for a trustworthy measurement,—that is, both are "Ready,"—the follower says "Ready," "Right," "All right here," "Mark," or any useful form of words.

Leader marks the place on the ground even with the zero mark on the tape, being careful not to release the tension, and to keep exactly in line. The mark may be the center of a spike stuck into the ground so as to stand firm, a scratch with the point of a spike, the point of a spike, carefully placed, or any other suitable mark.

Leader leave a spike at this mark.

Test the measurement by one or more trials after the mark at the zero end of the tape is made, until satisfied that the mark is correct for both distance and line.

Follower slips off his handle quickly, letting go the rear end of the tape, and picks up the spike at the mark from which the measurement proceeds.

Leader draws the tape forward 100 ft. on the line.

Follower advances to the spike left by the leader where he arrives about the time 90 ft. of the tape have pasesd the spike. He picks up the tape, lets it run through his hands till the 100 ft. end is almost in hand, when he calls "Hold," or "Halt," to the leader, and quickly slips on his handle.

Leader stops, and the tape is placed about on line.

Follower holds the 100 ft. mark to the spike and the operations for marking the first tape length are repeated till both are satisfied the work is correct.

Follower slips off his handle, takes up the spike where he is, and they proceed as before.

Thus continue until the leader has put down five spikes. While going forward to place the sixth spike the follower counts the spikes he has and calls "Five" to the leader, who counts those he has and answers "Five." They thus verify the count without delay. Leave a mark in place of the fifth spike.

Unless each has "Five," review the work and correct the errors.

Continue the measurement as before until the leader has put down his last spike. He calls "Out" to the follower, and stands by the last spike.

Follower slips off his handle, takes up the spike where he is, and goes forward, counting the spikes he has. He hands them to the leader and says "Ten."

Leader counts the spikes given him and says "Ten."

Here the count is verified and any errors found must be corrected. For this purpose the mark left in place of the fifth spike will make it necessary to remeasure but five tape lengths instead of ten, or more.

The eleventh spike keeps the measurement while the spikes change hands, the count is verified, and errors found and corrected. The measurement proceeds from the eleventh spike and the follower takes it up only after the spike next beyond it is set,—the same as he took up the spike at the starting mark.

Record the "Tally" of ten tape lengths.

So continue until a spike is set less than 50 ft. from the mark the measurement proceeds to. This spike may come before reaching that mark or beyond it.

Follower slip off his handle, take up the spike where he is, count the spikes he then has, and call the number,—as "Three,"—to the leader.

Leader count the spikes he has and answer with the number,—as "Seven."

Each retain the spikes he has and leave the one last set in the ground.

The sum of the numbers each has must be ten. If not, review the work and correct the errors.

The spikes the follower has show the number of tape lengths the last spike set is past tally mark, or from the place where the measurement began if less than ten tape lengths away.

Measure from the spike last set to the mark the measurement proceeds to, using the 50 ft. tape. Leader take the zero end of it and follower read the tape. Wind up this tape.

Record the total number of tape lengths, or hundreds of feet, as shown by the number of tallies passed and the number of spikes the follower has.

Record the measurement made with the 50 ft. tape.

Add the latter to the former, or subtract it therefrom, on the page of the note book, and make a record of the distance between the two marks the measurement was made to obtain.

Follower take up the eleventh spike.

Follower take all the spikes, count them, place one at the mark measured to, give the others to the leader and say "Ten."

Both must agree as to the count.

Proceed with the measurement of the next line as the first was measured.

Thus continue the work, at will.

Stand at the side of a steel tape to get distance, to read the tape, or to hold a mark on it even with another mark.

Stand on, or look along, a line, to give, or get, line.

16. **All measurements must be level.** Hold the two ends of the tape at the same elevation. Use the plumb bob to mark the point on the ground even with the mark on the tape. Measure down sloping ground if the descent is more then two per cent, on the best work. If the slope is too steep for the easy use of the whole tape, use it by parts, as directed below. Where there are several slopes along a line, descending in opposite directions, begin at the top of each and let the separate meaursements meet in the depressions, or valleys, between.

17. **In measuring down a slope,** draw out the whole tape along the line as if on level ground. Leader raise up the tape and, by direction of the follower lay it as nearly as may be exactly on the line. Hold the 100 ft. mark at the mark where the measurement begins, as before directed. Leader pick up the tape at any convenient place, where it will not be difficult to hold that place up at the same elevation as the 100 ft. mark. This place may not be at a mark on the tape, but it is better to use a regular mark on the tape if practicable.

Leader take his stand beside the tape so the hand and arm used to draw the tape taut will pass across the front of his body, in an easy and comfortable position, steadying himself by pulling the tape taut, and leaving his other hand and arm free to handle the plumb bob and string. The follower can easily hold against the pull of the leader, as he will be holding the 100 ft. mark at, or near, the ground. The leader will be out of line when beside the tape.

Leader hold the bob string at the exact point, or mark, on the tape to be used in this piece measurement. With this place, or mark, held at the proper elevation and on line, let the bob run down nearly to the ground and find where the mark to be made on the ground will come. Clear off the ground. Smooth the surface, if need be. Hold the place on the tape from which the bob string hangs, at different heights, and, by trial, find the height at which the piece of tape being used will mark the longest distance

on the ground. Nip the string tightly to the tape to show how much string to use.

Follower direct the leader to hold the bob exactly on line,—the place where the string is being at the proper height, found as above directed.

When both men are satisfied the conditions are favorable for a trustworthy measurement,—the tape being at a suitable tension and the plumb bob hanging steady and almost to the ground,—the leader lower his hands slightly, without releasing any of the tension, till the point of the bob touches the ground. Leader says "Right," carefully nipping the bob string at the exact place on the tape. Follower let his end of the tape move forward to give the leader some slack. Leader mark the place on the ground where the point of the bob touched.

Verify this mark by further trials, made with care, until both are satisfied the mark on the ground is correct for line and distance.

Follower slip off his handle, pick up the spike, where he is, and advance to the leader.

Leader deliver into the hand of the follower the exact place, or mark, on the tape where the bob string is. This may be done by the follower placing his thumb nail from the 100 ft. side against the thumb nail of the leader from the zero side, and nipping the tape securely, where no regular mark was used.

Follower hold this exact place, or mark, to the mark made beneath it on the ground.

Leader take up any other succeeding convenient part of the tape and measure it off on the ground with the same care, precauttions, and tests, as before, for both line and distance.

Follower advance to leader.

Leader deliver his place, or mark, to follower.

Continue these piece measurements on out to the zero of the tape.

Here leave a spike as usual.

Keep the marks on the ground in any convenient way. If spikes must be used, let the leader take one from the follower for every one he puts down between the 100 ft. and zero marks of the tape, at the time he delivers to the follower the intermediate places, or marks, he uses. Another size of nails may be used to mark with between the ends of the tape length.

Both men count the spikes they have at the end of every tape length where the measuring is difficult and see that each has his proper number,—both together having ten.

Continue the measurement at will.

By the method above outlined, a tape length is laid off without any adding of pieces. The tape does the adding and will make no mistakes. It is better to use marks on the tape, if practicable, to designate the piece measurements, as they are less liable to be lost sight of, and can be easily recovered if such is the case.

Be especially particular to keep these short parts of the tape on the line. Slight linear deviations give larger errors on short measures than on the whole tape length. It is much more difficult to keep the line on rough ground.

Ground may be so steep, rough, and covered with obstructions,—rocks, logs, rubbish, hillocks,—that the measurement must be made with a board not over ten feet long, having straight parallel edges and marked with feet and half feet marks. The ground marks must be kept on stakes. The board must be kept level with a carpenter's level, or some similar devise,—bubble tubes may be set in the edge of the board itself, and adjusted by reversion on two stakes driven in the ground. The line must be kept by a transit, at, or beyond, the foot of the slope, the measuring proceeding towards the transit. The mark on the lower stake may be made by a heavy, 4 or 5 lbs., plumb bob with a carefully adjusted point,—a millwright's bob might do,—or an accurate plumb rule used. There must be no wind. The piece measurements must be recorded as made, at their actual value, and added. If stakes must be set at equal intervals they must be placed by adding the proper piece measurements at the right places.

18. Measuring up a slope is similarly done. On the better class of work, avoid it, as it is especially liable to error. Only men of much experience should attempt it.

II. MEASURING WITH STEEL TAPES.

FIELDWORK.

19. Measuring set.

One hundred feet steel tape and reel.
Handles for same.
Fifty feet steel tape in its case.
Plumb bobs, with lines,—two.
Six-inch wire spikes,—eleven.
Axe. Stakes,—four.

Line staves may be needed for ranging lines.

Examine the articles as issued, or be liable for defects found upon their return.

20. Inspection of Plumb Bobs.

Look for the string,
the point,
the cap,
dents, and
evidences of abuse.

21. Inspection of Steel Tapes,—50 ft., or short tapes.

Unwind the tape.
See if the tape is wound wrong side in.
See if the reel works right.
Look for the box,
tape loose from reel,
breaks, splits, cracks, or kinks, in tape
dirt,
moisture,
rust,

screw holding reel in box,
reel handle,
knob on reel handle,
dents, or bends, in box, and
evidences of abuse.

22. Inspection of Steel Tapes,—100 ft., or long tapes.

Unwind the tape.
See if the tape is wound wrong side in.
See if the reel works right.
Look for the reel,
breaks, splits, cracks, or kinks, in tape,
dirt,
moisture,
rust,
numbers on tape,
tape handles,
reel handle,
parts of reel,
dents, or bends, in reel, and
evidences of abuse.

23. Inspection of Line Staves.

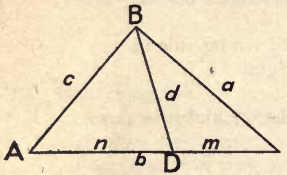
Look for bends,
scratches,
damaged points, and
evidences of abuse.

24. Reminders.

If the 100 ft. tape has been mended, test the spaces marked on it.
Keep the tapes wound up,—figures inside.
The zero end of a tape goes ahead.
Count the spikes as directed .
Verify the count between the fifth and sixth spikes.
The spikes the follower has show the distance past the last tally mark.

Verify the count at the last spike set.
Do not pull up the last spike till the record is made.
Record the number of even hundreds of feet.
Record the distance measured with the fifty feet tape.

25. Survey of a triangle, about 450 by 250 feet.



$$d^2 = \frac{(a+m)(a-m)}{b}\,n + \frac{(c+n)(c-n)}{b}\,m$$

$$\text{Area} = \sqrt{s\,(s-a)\,(s-b)\,(s-c)}$$

$$s = \tfrac{1}{2}(a+b+c).$$

26. Instructions.

On rough ground mark a triangle with small stakes, A, B, C, so that A C is, by estimation, about 450 feet, and B is, by estimation, about 250 feet away from A C. Set D anywhere in A C. Be particular to place D exactly on A C. Use a plumb line to range with.

Witness A, B, C, and D, following the form below.

⊙ A. A nail in a stake driven flush with the ground, standing on the third prominent ridge N. of the Detroit Observatory, Ann Arbor, Mich., from which a *Witnesses.* Hickory, 12″ in diameter, bears N. about 55° E. 72.′3 to its center, and a

B. Walnut 27″ bears S. about 35° E., 261.′4 to cen.

Spike in root of Sycamore 32″, S. about 45° W., 47.′13.

Spike, E. face of brick wall near S. E. corner of barn, N.W'ly, 34.′27.

Measure A B, B C, C D, D A, and B D. Find the value of *d* from the above equation. Subtract it from B D, measured, and show the error + or —. Compute the area in square feet. Reduce this to acres. Make a neat plat of the triangle to scale, on the cross ruled page of the field note book. Record all of these matters in the field note book.

27. **Measure the distance, eight times,** between two marks about 1000 feet apart. The cement walk on the east side of the campus is about 1000 feet long.

Drive two stakes, by estimation, about 1000 feet apart, on a smooth piece of ground. Tops of stakes flush with surface of ground. Drive a nail in each stake. Witness each stake. Set up a line staff about two feet beyond each stake, on the line of the stakes, and standing plumb.

Measure the distance carefully between the two nails. Return, measuring the distance carefully, with the same person for leader.

Change positions, the person acting as follower taking the lead.

Repeat the measurement, out and back, with the new leader.

Change positions.

Repeat the measurement, out and back.

Change positions.

Repeat the measurement, out and back.

Record the measurements, as they are made, showing in the book who is leader and who is follower for each one.

Add the eight measurements. Divide by 8. Find the average measurement.

Subtract each measurement from the average measurement and write the difference, with its sign, opposite each measurement, forming a column of "Errors."

Add the errors. See if the sum equals zero. If not, review the calculations and correct the figures.

Record all these matters in the field note book.

III. HANDLING INSTRUMENTS.

INFORMATION.

28. Transit.

Observe with certainty how it is packed in its box, so it can be properly returned to its place. Do not unpack it and take it from its box until sure it can be put back precisely as found.

Examine the tripod. See that no parts are missing. See that all the shoes on the free ends of the legs are tight. See that the wing nuts that clamp the legs to the top casting all have washers, and will clamp the legs firmly to the casting. If a tripod is set up to receive an instrument for use in making observations, the legs will be properly clamped by the wing nuts, in most cases, when they are tight enough so as to just be held in position at the usual slope, without dropping, if the tripod is raised, by its top, off of the ground. In a windy time, they may be clamped tighter to steady the instrument. See that the screw on the neck of the top casting is in good order. The tripod being in order set it up on the floor, or the ground, to receive the transit when unpacked.

Many common transits are screwed on to a board which slides into the transit box with the transit on it. Lift the transit by its base, or its plates, not by its standards, transit axis, or telescope. Set the board in a secure place,—on top of the box will often do, but do not let go of the transit in such a place. Release the spindle clamp. Start the screw that connects the transit to the board. Hold the transit with one hand to keep it from falling, and with the other on the leveling screws, unscrew the transit from the board by turning the base to the left. In this manner separate the transit from the board without danger of it receiving a fall.

In the manner described, or any other method, adapted to the way the transit is packed, take it from its box.

Release the spindle clamp. Release the transit axis clamp. See that the plumb bob chain hangs central and free from beneath the base plate.

Place the transit on its tripod. With one hand hold of the side of the transit to keep it from falling, and with the other hold of the leveling screws so as to turn the base, screw the base on to the tripod. At the last take hold of the base with both hands and make sure the transit is screwed down firmly. If the screw thread in the base plate of the transit does not engage readily with the thread on the tripod, steady the instrument with both hands so the screws bear fair and turn the transit slowly and carefully to the left till the screws drop together. Turn to the right and screw on the instrument.

Take off the cap to the objective of the telescope. Put on the shade. Put the cap in the box where the shade was.

Take the reading glass. Put it in a pocket, handy to reach and where it cannot get lost. Some good instrument men tie the reading glass about their necks with a strong string, like a watch.

Take the plumb bob. Tie it on to the chain with a sliding horse knot, tied with a bow, so the bob can easily, and quickly, be set at any required height.

Put the board in the box. Close and fasten it. Set it away in its place.

Turn the telescope straight up and clamp slightly.

Release the spindle clamp if not released.

Put the plumb bob in a pocket.

Take hold of the tripod by two of its legs,—one in each hand,—with the third leg towards one side of the body. Lift the instrument and draw the legs together with one motion, raising and inclining it to rest, nearly balanced, on the shoulder. Let go of the leg in the hand that is on the same side of the body as the shoulder on which the transit rests, holding the instrument securely with the other. Pass the free hand between the two free legs and grasp the one the other hand holds, releasing that hand. By so doing the instrument always will be held securely.

29. Setting up Transit. Making a Pointing.

Take the instrument to the work.

To set the transit down, grasp two tripod legs,—one in each hand,—holding one vertical, and steadying the instrument with the other.

Set the vertical one in its place on the ground, if the transit is to be set up over a mark,—as a nail in a stake.

Grasp the other two legs,—one in each hand,—and spread them out to such a position that the base plate, on which the leveling screws stand, appears to be level when these legs also stand on the ground . The tripod legs should be spread apart far enough so the transit will not only be in no danger of an upset, but so it will stand steady while observing with it.

Take the plumb bob from the pocket and let it hang beneath the transit.

If the transit does not stand over the mark on the ground it is to be set up over, lift it by the tripod, bodily, and move it so it will.

Force the tripod legs into the ground, or spread them apart, or place their feet, so the plumb bob hangs nearly over the mark, and the tripod will stand firm. Instruments are often set up too insecurely to permit of good work being done with them. On a hard surface like rock, or a street pavement, the shoes on the feet of the tripod must be tight or the tripod will wobble on them. Besides they must be set where there is no danger that they will slip.

Release the wing nuts at the tops of the tripod legs. Tighten them again.

Release all of the leveling screws, or other device, that permits the use of the shifting center. Shift the transit on its base plate, or shifting center, till the point of the plumb bob hangs exactly to the mark over which the transit is being set up.

Release the clamp to the transit axis.

Release the clamp to the spindle axis, if not already released.

Release all the leveling screws, if not released.

Turn the transit on its spindle, by taking hold of the edge of the plate, or the feet of the standards (not the telescope), so the bubble tubes will stand parallel to opposite leveling screws.

Operate the leveling screws parallel to the transit axis till the bubble tube they control reads level, leaving the screws loose.

Operate the other pair of leveling screws till the bubble tube they control reads level, leaving them a little tight.

Operate the first pair again till the bubble tube they control reads level, leaving them a bit tighter.

Operate the other pair again as before, leaving them tighter.

Operate the first pair again as before, leaving them tighter.

A few touches more and both levels should read level, and the leveling screws be bearing firmly enough so the transit will not turn on the base plate. They must be considerably tighter when there is much wind.

See if the point of the plumb bob hangs exactly to the mark. If not release the leveling screws, center the transit carefully, and level again. The transit is now "Set up."

Turn the transit on its spindle by taking hold of the edge of the plates or the feet of the standards, not the telescope, or the tops of the standards.

To turn the telescope on the transit axis take hold of the eyepiece end of the body tube, not the eyepiece itself. To reverse the telescope turn the eye end down, take hold of the body tube above the transit axis, not the shade, and complete the reversion.

The leveling screws should always turn with the same resistance, and smoothly, if the instrument is leveled as directed. If this is not the case, clean them, and the hollow screws they work in. When the instrument is leveled the leveling screws should be bearing evenly and firmly,—all alike in every respect.

Place the tripod on the ground, if practicable, so the instrument man will stand between the feet of two of the tripod legs, ordinarily, while at work, and not astride of one of them.

To direct the telescope towards an object, release the spindle clamp and the transit axis clamp, if both are not released. Turn the transit on the spindle with one hand to the edge of the plate, and turn the telescope with the other hand to the eyepiece end of the body tube, until when looking over, or under, the telescope it appears to be pointed in the right direction.

To find the cross wires, first release the clamps to the transit axis and spindle.

Open the peep hole to the eyepiece.

Direct the telescope to the sky or a light colored object.

Look through the telescope.

Operate the device for moving the eyepiece until the cross wires appear clear, distinct, black lines across the field of view. Make them appear as sharp and well defined as possible.

To focus the objective direct the telescope to look at any object.

Look through the telescope.

Bring the object into the field of view by some slight movements of the transit, if needed.

Move the focussing ratchet to the objective until the object appears as clear, sharp, and distinct, as it is possible to make it.

Move the head slightly but still be able to look through the telescope.

See if the cross wires appear to slip about on the object. If so, change the focus of the objective, and perhaps of the eyepiece also, slightly, till the motion of the head, above mentioned, causes no change in the relative position of the object and the cross wires.

When the objective and eyepiece are both properly focussed the cross wires should appear to be painted on the object, and it should not be possible to change their relative position by any motion of the head. The view of either the object, or cross wires, or both, may not be quite so perfectly distinct and clear as before these final changes in the setting of the objective, or eyepiece, but should be.

After the telescope is in proper focus, clamp the spindle and plate.

By means of the slow motion screw to the spindle, make the vertical cross wire cover, or bisect, the object, or mark, sighted to.

This is "Making a pointing."

If the plate must be set at any given reading for a designated pointing, do this by the plate clamp and slow motion screw, before making the pointing.

Make the pointing by means of the spindle clamp and slow motion screw, as above.

Read the plate verniers. See if the readings are correct. If so, the pointing is finished. If not, repeat the work till they are.

30. Line Staves. Pickets. Sight Marks.

Line staves are used in transit work. A common one is made of ½" wrought iron pipe, one end closed, the other steel pointed, about 7 ft. long, painted white, with the second, fourth, and sixth foot from the top, or closed end, painted red, or black. A line staff should be straight, true, and the point exactly in the axis of the body of the rod. Set the point of the rod on a board. Twirl it in a vertical position. It should revolve true and not wobble. Watch it at the place where the steel point is welded on. This makes a practical staff for general use. On some city and bridge work a ½" solid steel rod, about five feet long, turned true and its point centered in a lathe, painted the same as the pipe, is found to be very satisfactory.

The line staff is held on a point, or mark, from which line is to be taken, or to which an observation is to be made, and used as a mark to sight to. It is also used to find where any line comes by being set in line by the transit.

To hold a line staff, stand squarely behind it as viewed from the instrument; face the instrument; settle the body firmly on the legs with the feet apart, alike on both sides; let the staff pass centrally along the body from the nose down, the person having a sense that the body is plumb; and

hold the staff with both hands brought together at the same place on it, the ends of the fingers and thumbs embracing it, and with the elbows extended alike on both sides. Practice this in calm weather, and there will be less trouble in holding the staff plumb when the wind blows.

Sight as near as possible to the point of a line staff. Never trust the line when only two or three feet of the top can be seen.

Many other things are used for marks to sight to in transit work. A plumb bob string, a small nail, or the point of a lead pencil, are suitable marks up to 300 ft. or so; a lead pencil, or one of the 6″ spikes from the measuring set, from 100 to 500 or 600 feet. From thence on for a couple of miles the line staff, made of ½″ pipe is suitable. These distances are subject to modification according to the conditions of seeing. The line staff is used within short distances from the transit. The tendency is to use much too large marks to sight to. Neither is there always sufficient care bestowed in selecting and placing them so the pointing on them will be precise.

One of the more useful marks in transit work is a picket. Where there is timber, cut a stick 1″ to 2″ thick, about a foot longer than the height of the transit as usually set up. Make a straight blaze along about two feet of its top about ¾″ wide for sights from one to three thousand feet long. Choose the lightest colored wood, as hickory, or basswood. Cut the top square across the blaze with a slant back from the blaze. Sharpen the bottom end to go in the ground. Before moving the transit turn its telescope on to the mark where the next set up is to be. Stick up this picket with the straight blaze set to look plumb from the forward set up place, so it will stand firm with the blaze close up to the eyepiece. Range the blaze fairly behind the telescope. If the telescope is inverting, look through it from the objective end. If the picket is not too close the blaze may then be set in the middle of the opening. If the telescope is erecting sight over it, or beneath it, and on each side of it. At the new set up set the verti-

cal cross wire to bisect the blaze on the picket at the place that was at the eyepiece. This picket is better than a line staff held up on the mark and dispenses with one man. Any other kind of a stick may be used, as a piece of board.

Short sights should be avoided. Sometimes this cannot be done. Then use a plumb bob string, a fine nail, a pencil point, the back of a pocket knife blade, or some similar small object. In sighting to a blumb bob string set the cross wire on it as near the place from which it is suspended, as practicable. Often the plumb bob string may be held in the hand grasping a line staff, or long stake, stuck into the ground to one side of the line of vision, and inclined till the point of the bob is exactly to the mark it is desired to sight to. This will steady the hand holding the string.

A picket,—long or short,—of suitable thickness may be stuck in the ground back of a mark and inclined over the mark till a plumb bob string held to the center of its top brings the point of the bob to the mark. Sight to the top of a picket set in this way, where the plumb bob string was.

A very useful mark to sight to, both for short sights and those up to a thousand feet, or more, is made by sticking a nail, fine, or thicker, as may be needed, twice through a piece of white paper so that the paper will form a back ground for the nail when set in line. Fold the paper, or cut it, into a rectangle. Stick the nail exactly central in the paper and parallel to the sides of the rectangle. This mark is often used by first setting the cross wire on the line where it is to be set by reference to a mark on that line by some other means, as a line staff, or a plumb line, and then setting the nail on line with the transit. Drive the nail plumb. After the nail has been set test the steadiness of the transit by again sighting to the reference mark. The person with the line staff or plumb line can then be released for other duty, the nail being used for reference. If prepared and set as directed, this mark can be referred to for line, from any place where the paper can be distinctly seen.

In sighting to a stick, or mark of any kind, set to show a line, use the very spot that was set on the line, not the other part.

31. Locating a Mark.

To locate a mark on a designated line, set up the transit at a mark on that line and set the line of sight (vertical cross wire) on another mark on that line, as above directed.

Turn the telescope on the transit axis to look to the place where the new mark is required. Set a line staff in line at this place. Drive a stout stake, or plug, where the staff stood till flush with the ground. While the stake, or plug, is being driven, see that the point of the plumb bob is to the mark, that the plate levels read level, and that the vertical cross wire strikes the other mark on the reference line. When the plug is down, and the transit exactly set, and standing so, set the staff precisely in line on top of the plug,—the staff being plumb. Look again to the stability of the transit, and, finding it secure, signal "All right." Drive a small wire nail at the mark in the plug made by the point of the staff, leaving the head up a little. There are many other ways of marking points.

Measure, and record, distances from the nail in the plug to three, or more, of the nearest and most permanent objects, such as trees, foundations, hydrants, lamp posts, or pumps, with their directions from the plug and plain descriptions of them. Also measure and record the distance from the nail in the plug to some other mark on the same line.

32. Signals.

Stand squarely behind the transit when giving signals. Make the motions slowly, especially if they are to be read at some distance. It is usual to move too quickly in giving signals.

To say "Move the line staff to the right," stretch out the right hand and arm level.

To say "Move the line staff to the left," stretch out the left hand and arm level.

Let one down by the side before raising the other.

To say "All right," raise both hands above the head and with the arms fully extended, bring them slowly down to the sides.

To say "Hold up the line staff," throw the weight onto one foot and extend the opposite hand and arm as high as they will reach.

To say "Plumb the line staff," incline the head in the direction the top of the staff should go.

To say "Come here," beckon with the hat, or head covering. The transit man should not "move up" until called in this way.

Many additional special signals will grow up in any party working for some time on the same work.

The signals with a handkerchief, a flag, or the like, are based on those given.

To the right,—show the flag to the right.

To the left,—show the flag to the left.

All right,—wave the flag slowly back and forth, aloft.

Hold up staff,—stretch up the hand with the flag in it.

Plumb the staff,—stretch up the hand with the flag in it and incline the flag in the direction the top of the staff should go.

Come here,—raise the flag staff with the head cover on its top.

A whistle is very useful for signalling. It is made of tin, with a "barrel" about one inch in diameter. Most tinners know how to make one.

To the right,—one blast.

To the left,—two blasts.

All right,—three blasts.

Hold up the staff,—one long blast.

Plumb the staff,—one rather long blast followed by one toot for top to the right, or two toots for top to the left.

Come here,—two long blasts.

Something in the way,—repeated short toots.

Come back and clear out the line,—short toot, then a blast, repeated as the axeman comes back till he is brought to the spot. He may get too far back.

Go ahead,—a blast, then a short toot. So bring him to the spot. Then signal him right, or left, as above, and also

Up,—two toots and a blast.

Down,—a blast and two toots.

So it is possible to bring his hand to the thing that makes the trouble. When he has the line clear, give him,—All right,—Go ahead.

All hands this way,—four blasts.

The above are illustrations which may be greatly extended if occasion requires.

Right and left must always mean with respect to the direction in which the line is going and not the direction in which the telescope on the transit may chance to be looking.

33. Putting away Transit.

Bring in the transit when through work.

See that it is in good order for immediate use. If not, make it so.

Put it in its box at once. Do not leave it standing around on its tripod.

The place for an instrument is in its box, when not in use.

The place for the box, with the instrument in it, is where the temperature is steady and where it will be let alone.

Keep in the box with the instrument a fine camel's hair brush and a piece of the softest chamois skin for the lenses. Keep there another camel's hair brush, such as painters use, about an inch wide, for dusting off the instrument; also soft cloths for wiping it.

Take off the plumb bob, wind up its string neatly, and put it in its place in the transit box.

Put the reading glass in its place in the box.

Release the spindle and transit axis clamps, if not released.

Take off the shade and put it in its place in the box.

See if the objective and outside eyepiece lens need dusting off. If they do, dust them off with the lens brush. They may need slight wiping with the chamois. Beware of scratching them.

Close the cap to the eyepiece.

Cover the objective with its cap after seeing that the cap is clean.

Dust off all parts of the instrument with its brush, if it needs dusting. Wipe it with cloths if required.

Release the leveling screws.

Place the transit central on its base plate.

Tighten the leveling screws rather firmly, making them all even so the plates between which they work will be parallel.

Unscrew the instrument from its tripod.

Screw it on to its sliding board, if there is one.

Clamp the spindle, and release the plate clamp.

Slide the board into the box carefully with the instrument on it and in its proper position.

By trial and examination set the telescope and other parts so as to be as clear of the box as possible.

Clamp the plate and transit axis but not very hard.

See that the door of the box shuts freely,—no crowding.

Close the box. Fasten it. Lock it. Put the key away. Set the box in its place. Close and strap the tripod. Put it away in a safe place.

If there is no sliding board, place the transit in its box in its proper position, so the spindle clamp and transit axis clamp are accessible. When the instruments is securely placed clamp those clamps slightly, also the transit axis clamp. See that the box closes freely. Close and lock it, and set it in its place.

If an instrument comes in wet wipe it off with soft cloths and brush the moisture off of the outside of the objective and eye lens with the lens brush, or wipe them with the chamois, or both.

Unscrew the instrument from its tripod, and set it in a warm (not hot) place to dry, where it will not be touched.

If there is water between the glasses of the objective, or within the eyepiece, or inside of the tubes, or between the plates, let the instrument stand in a warm place for some time (say over night) and it may come out. Do not make haste to be taking things apart to get it out. While waiting for the transit to dry, put the reading glass, plumb

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bob, and shade in their places in the box. Leave the cap off of the objective and the eyepiece cap open till the instrument is dry. When it is dry, dust and clean it, if it needs it. See that the parts are working freely. Put it away in its box.

If an instrument has to be transported, have a packing case well upholstered within on all six sides to set the instrument box in. It should fit snug.

For the reading of an angle see 50.

34. Level.

For information relating to the following subjects read what is said regarding them under Transit. There should be no difficulty in applying the statements to the handling of a level.

Packing in its box.

Tripod.

Screwing to tripod.

Cap over objective, and shade.

Setting box away.

Carrying on shoulder.

Setting down. Does not have to be set up over a mark.

Finding crosswires.

Focussing objective.

Lift the level by its base or by the bar upon which the telescope is mounted,—not by the telescope.

In leveling this instrument, turn the bar to stand over a pair of leveling screws.

Operate this pair till the bubble tube reads nearly level, leaving the screws loose.

Turn the bar over the other pair of leveling screws.

Operate this pair till the bubble tube reads level, leaving them a little tight.

Turn the bar back over the first pair,—do not reverse it.

Operate this pair again till the bubble reads level, leaving them a bit tighter than the other pair.

Turn the bar back over the other pair,—do not reverse it at any time while leveling this instrument.

Operate this pair till the bubble reads level and they are as tight as will be needed.

Turn the bar back over the first pair.

Operate them till the bubble reads level, and they are tight enough.

A few touches more and the bubble should read level in both positions. The bubble tube is much more sensitive than those in the plate levels of a transit and correspondingly more difficult to set to read level.

The leveling screws should bear evenly, not too tight, and turn by the application of the same force to each. They need be only tight enough to hold the bubble level. When there is no wind at all they may be entirely loose, the level standing upon their bottom ends, with no pressure on the ball and socket joint in the base plate.

The level is then ready for observing, although may be the bubble will not read level if the bar should be reversed.

It is now said to be set up.

35. Leveling Rod.

There is used with a level, a leveling rod.

This is an accurately divided wooden rod. The unit of division may be anything, but the foot and the meter are probably the most used.

There are target rods and speaking rods,—so-called.

On the target rod is a target, or two in some cases, to which the pointing of the level is made. After the target has been set by direction of the leveler, the rodman reads the distance of the sight line on it from the zero of the divisions, or graduations, usually with the aid of a vernier.

The speaking rod has no target. The leveler reads the rod without assistance from the rodman, by noticing where the horizontal cross wire appears to lie on the graduations.

The target rods in most common use in the United States are the Boston Rod, the New York Rod, the Philadelphia Rod, and the Troy Rod. There is some choice in the kind and plan of a rod for different kinds of work.

The targets in common use are of a pattern which introduces a considerable uncertainty into the rod readings, especially when at some distance from the level. These patterns can be easily improved by using central white spaces on the target, of increasing width towards the sides of the target, these spaces to be bisected by the horizontal cross wire, using the wider ones on distant sights. These spaces should be rectangular in form.

Speaking rod patterns are of a very great variety of forms. Avoid those containing oblique lines, points and sharp angles. The pattern should be made up of rectangles, painted alternately white and black. The pattern should be so arranged that the horizontal cross wire will always lie on a white surface, except at the edges of the black rectangles. The rectangles may be one-tenth of a foot high, or a half a tenth of a foot, the hundredth of a foot, where needed, being estimated by the leveler.

Do not infer because a target rod is read to thousandths of a foot by a vernier, while the hundredths of a foot on a speaking rod are "Guessed at," and the thousandths "Thrown away," that the target rod is either more precise, or more trustworthy.

Target rods are made in more than two pieces, for obtaining a longer extension, or a shorter length when closed.

Speaking rods are hinged, or jointed, for compactness. They are also made in the form of a broad tape, to be fastened to a board for use, and rolled up when not in use,—the "Flexible" rod. For many uses, take a strip of wood of any suitable length, $\frac{7}{8}'' \times 2''$, and tack on to it a piece of a metallic tape measure. Mark off, on the stick, the even feet from the steel tape, and tack on the tape so its foot marks fit these. This rod may be of any length, up to fifteen feet. It is very useful on rough work.

The leveling rod is used for measuring the vertical distance between the line of sight of the level and any object. The object may be below the line of sight of the level, as is commonly the case in surveys upon the surface of the ground, or above it, as in overhead work, which may be

met with in tunnels, mines, setting of steel beams, or in leveling shafting.

The rod is used by holding it vertical, or waving it slightly, so as to measure the shortest distance from the line of sight of the level to the object upon which the foot of the rod is held. In leveling shafting, a large hook is sometimes screwed into the foot of the rod and the rod hung from the shafting by this hook. A hook with a square turn is used, also one with a circular curve of larger radius than the shafting. The latter can be used on shafting of any size smaller than the curve of the hook, while the hook with the square turn sets lower on the smaller shafting and requires a correction to the rod reading in addition to that for the size of the shafting when the axis of the whole line, it may be containing different sizes, must be placed at the same height.

When using a target rod, the rodman should move the target as directed by the leveler, with an uniform, steady, even, motion, not by jerks, and spurts.

When using a speaking rod the rodman should be very particular to hold it plumb. Read the suggestions for holding a line staff plumb.

When using any rod the rodman should stand squarely back of the rod and face the level.

36. Signals.

Target to be moved down, leveler lowers his hand and shows the back of it to the rodman, who keeps the target going down with an even motion until stopped by a signal from the leveler.

Target to be moved up, leveler raises his hand and shows the inside of it to the rodman, who keeps the target going up with an even motion until stopped by a signal from the leveler.

As the sight line on the target approaches the horizontal cross wire the leveller quickly throws his hand and arm out to a horizontal position in time to catch the target with its sight line on the cross wire. This he will soon learn

to come very near doing. The rodman seeing this signal, as quickly stops the target and holds it from slipping. A slight adjustment of the target will bring it exactly to place.

The leveler extends both arms to say "All right."

To say "Plumb the rod," the leveler inclines his head the way the top of the rod should go.

To say "Wave the rod," the leveler raises his hand above his head and waves it back and forth towards and away from the rod.

To say "Hold up the rod," the leveler throws his weight on to one foot and raises his opposite hand as high as he can reach.

To say "Clamp the target" or "Clamp the rod," the leveler whirls his hand around as if turning a crank.

In a wind the rodman may not be able to make the leveler hear distinctly his call of the figures in the reading of a target rod. It is quite easy to mistake "five" for "nine." The rodman lays his rod on the ground and stands facing across the leveler's line of vision. He extends his arms wide apart vertically and brings the palms of hands together, not too quickly, as many times as there are units in the figure he wishes to communicate,—as seven times for figure seven. He makes a short pause. He makes the next figure in the same way, and so on till the leveler signals "All right," that he understands them all.

To say "Repeat the rod reading," the leveler waves his hand with jerks and mixed movements, signifying confusion.

A rod is "Read" by repeating the figures of the entire reading, speaking the feet (or other units) first,—as "Eleven," —pausing slightly, and following with the figures in their order in the decimal part of the reading.

Shouting, noise, and racket, are no part of surveying. Keep as quiet as possible, and give undivided attention to the work. It takes this to avoid errors, mistakes, and blunders.

"Short rod" means a movement of the target within the length of the foot piece, or bottom piece, of the rod.

"Long rod" means a movement of the target beyond the length of the foot piece of the rod.

For long rod with the "New York" or "Philadelphia," rod set the target exactly to the short rod reading at which the long rod reading begins,—as at 6.500, on some New York rods. Be particular about this, or the long rod readings will be wrong.

For long rod with the "Boston" simply invert the rod and take the reading from the other vernier.

For long rod with the "Troy" rod, the leveler sights to the upper target and adds the distance,—as 6 ft.,—between the sight lines of the targets, to the reading from the vernier.

37. Taking a Rod Reading.

Hold the rod vertically with its foot on the object upon which a rod reading is to be taken.

Direct the telescope to look at the rod.

Focus the objective sharply on the rod.

See if the bubble reads level. If not, start the leveling screws that are nearest parallel to the level tube slightly and set them so the bubble will real level and stand at that reading.

By directions from the leveler, the rodman sets the target so its sight line precisely matches the horizontal cross wire.

Clamp the target.

See if the bubble still reads level. If not, repeat the work, till it does.

Wave the rod slowly back and forth, towards and away from the level, past the vertical both ways, if the rod reading is over six feet. If there is much wind wave the rod for a reading of over four and a half feet.

See if the target is set to match its sight line precisely to the cross wire once in its path, as it is waved, and passes below the wire each way from that one place.

See if the bubble reads level.

When satisfied, read the rod.

Do not wave the rod for a short reading,—say up to two or three feet,—or the reading will be wrong.

Always be sure the bubble reads level for every rod reading whether the level is in adjustment, or not.

The above directions provide for a rod reading having all the precision possible, with the instruments used. Such rod readings should be taken on all Bench Marks, Turning Points, or other objects, upon which the transfer, continuation, or preservation, of the levels depend.

In placing pegs, or other marks, for construction it is customary to read the rod to hundredths of a foot, and not to use quite the extreme care above outlined.

In taking rod readings on the surface of the ground merely to get its elevation, it is customary to seek to obtain their correct value to the nearest tenth, or half tenth, of a foot, and much less care is needed.

The above directions for the target rod may be adapted to the use of the speaking rod.

38. Putting away Level.

Bring in the level and rod when through work.

See that the level is in good order for immediate use. If not, make it so.

Put it in its box at once. Do not leave it standing around on its tripod.

The place for an instrument is in its box, when not in use.

The place for the box, with the instrument in it, is where the temperature is steady and where it will be let alone.

Keep in the box with the instrument a fine camel's hair brush and a piece of the softest chamois skin for the lenses. Keep there another camel's hair brush, such as painters use, about an inch wide, for dusting off the instrument; also soft cloths for wiping it.

Take off the shade and put it in its place in the box.

See if the objective and outside eyepiece lens need dusting off. If they do, dust them off with the lens brush. They may need slight wiping with the chamois. Beware of scratching them.

Close the cap to the eyepiece.

Cover the objective with its cap after seeing that the cap is clean.

Dust off all parts of the level with its brush if it needs dusting. Wipe it with cloths if required.

Release the leveling screws.

Tighten them rather firmly, making them all even so the plates between which they work will be parallel.

Unscrew the level from its tripod.

Put the level in its box.

See that the box closes freely,—no crowding.

Close the box. Fasten it. Lock it. Put the key away. Set the box in its place.

Close and strap the tripod. Put it away in a secure place.

In case a level comes in wet follow the instructions given for the transit when wet.

If a level has to be transported, have a packing case well upholstered within on all six sides to set the instrument box in. It should fit snug.

39. Putting away Leveling Rod.

See that the leveling rod is in good order for immediate use. If not, make it so.

Put it away in its place at once. Do not leave it standing around.

Dirt and damage from use, or abuse, make a rod worthless.

Clamp screws can be cleaned. Leave no oil when done.

Clamps can be refitted.

Metal parts can be fastened better.

Fixed targets, as on the Boston Rod, can be fastened on more securely.

Common hard soap will lubricate clean wooden parts.

If the rod is dim to read from dirt, wash it with soap and water.

III. HANDLING INSTRUMENTS.

PRACTICE.

Setting up, and putting away instruments.

40. Transit.

Outfit.
- Transit.
- Axe, stakes, and nails.
- Line staff.

Examine the articles as issued or be liable for the defects found upon their return.

41. Inspection of Transits.

Try all clamps and slow motion screws.

Try all rotary motions.
- Spindle axis.
  - Plate.
  - Verniers.
- Transit, or telescope axis.

Try focussing motions.
- Objective slide.
- Eye piece.

Try leveling screws.
- If not on center of base plate with leveling screws even and firm, return to user.

Look for cross wires,
- plumb bob chain,
- reading glass,
- plumb bob,
- shade,
- cap over objective,
- screw driver,
- adjusting pins,

camel's hair brushes,
damage to box,
broken, or cracked, bubble tubes,
scratches on the objective,
cap on eyepiece, and
evidences of blows, upsets, or abuse.

Examine all circles and their verniers for scratches, dents, and injuries of any kind.

42. Inspection of Tripods.

Look for shoes,
loose shoes,
wing nuts,
bolts,
breaks, or splits, in legs,
damage to top screw,
cover cap,
dents, or bends, in top casting, and
evidences of misuse or abuse.

43. Reminders.

Observe narrowly how the transit is packed in its box.

See that the shoes on the tripod are tight, and the screw on it in good order.

Lift the transit by its plates, or base,—not by the transit axis or standards.

Put the cap in the box.

Put on the shade.

Take the plumb bob and reading glass.

Put the box away.

Release all the leveling screws before beginning to level the transit.

Focus the telescope carefully.

Make pointings with precision. Bisect the mark accurately.

Sight to the bottom of the line staff, if practicable.

Use good stakes,—no splinters.

Use good plugs,—4″ or more, across the top,—driven flush with the ground,—not stakes. These for instrument points.

Make good notes. They cannot be too good.
Watch all the stuff all the time, or some of it will get lost.
Each person be responsible for certain articles.
Before moving away from a work place, find all of the outfit and account for every article.
When through work, put every thing away, in order for immediate use, and in its place.

44. Take a transit out of doors. Set it up properly over a nail in a stake, or plug. Learn and operate the different motions and parts. Find the cross wires. Set the line of sight on a mark. Locate a new mark, as a nail in a plug, on the line to the mark sighted to. Take down the transit, repack it in its box properly, and put it away.

45. Level.

Outfit.
Level.
Leveling Rod.
Axe, and stakes.
Examine the articles as issued or be liable for the defects found upon their return.

46. Inspection of Levels.

Try clamp and slow motion screw.
Try rotary motions.
Spindle axis.
Telescope in wyes.
Try focussing motions.
Objective slide.
Eyepiece.
Try leveling screws.
If not even and firm, return to user.
Look for cross wires,
shade,
cap over objective,
screw driver,
adjusting pins,

camel's hair brushes,
damage to box,
broken, or cracked, bubble tubes,
scratches on objective,
cap on eyepiece, and
evidences of blows, upsets, or abuse.

47. Inspection of Leveling Rods.

Try the clamps.
Try the slide.
Look for clamp screws,—bent, broken, or lost,—
loose target, on Boston, or Troy, Rods,
scratched, or bent, target, dirt,
scratches on scales, or face of rod, dirt,
damaged, or lost, verniers,
splits, or breaks, in tongue and groove, and
evidences of blows, falls, or abuse.

48. Reminders.

See how the level is packed in its box.
Examine the tripod.
Lift the level by its base or bar.
Put the cap in the box.
Put on the shade.
Put the box away.
Release all the leveling screws before beginning to level the instrument.
Focus the telescope carefully.
Set the target accurately.
See that the bubble reads level for every rod reading.
Hold the rod plumb.
Watch all the stuff all the time, or some of it will get lost.
Each person be responsible for certain articles.
Do not set a leveling rod where it is liable to fall down and be broken. This is too common. Lay it on the ground.
When through work, put every thing away, in order for immediate use, and in its place.

49. Take out of doors, a level and rod. Set up the level. Learn and operate the different motions and parts. Having set it up firmly and leveled it carefully, take a rod reading on a B. M. Find H. I. Take other rod readings on various places and find their elevations. Take down the level, repack it properly in its box, and put it away. Put the rod away.

Learn to use both the target rod and the speaking rod.

IV. SURVEY OF A TRIANGLE.

INFORMATION.

50. Reading an Angle.

Set up the transit over the mark at the vertex of the angle. Clamp the plate. Set the line of sight on the object which marks the left hand side of the angle, using the spindle clamp and slow motion screw. See that the plate levels read level.

Read the plate. Record the readings.

See that the line of sight still strikes the object on which it was set.

By repeated examinations make sure the transit is stable, level, the line of sight on the object, and the plate readings recorded correctly.

Release the plate clamp.

Set the line of sight on the object which marks the right hand side of the angle, using the plate clamp and slow motion screw.

See if the plate levels read level. If much out, repeat all the previous work and adjust these levels if necessary. So make sure of the setting of the transit for the second object.

Read the plate. Record the readings.

See that the line of sight still strikes the object upon which it was last set.

Release the plate clamp.

Set the line of sight again on the left hand object, using the plate clamp and slow motion screw.

See that the plate levels read level.

Read the plate. Record the readings.

See that the line of sight still strikes the left hand object.

See if the first and last readings are alike, or nearly so. If not, repeat the work till they are.

Follow the form herewith.

Reduce the value of the angle by one of the methods shown.

University of Michigan.

1897-10-26

Reading the Angles of a Triangle

Temperature unseasonably high.
Sun shining with a burning heat.
Moisture in air bad. Seeing poor.
Instrument affected by the heat.

A. B. C. Designate the vertices of this tri

⊙ A Is a nail in a stake driven flush
ridge S. of Detroit Observatory, A
Hickory 12" in diameter bears N. abou
B. Walnut 27" in " " S. "

⊙ B Is a nail in a stake driven flush
Spring St. & Chubb Road, Ann A
corner fence post. Other witnesses

⊙ C Is an iron pipe 3/4" × 36" driven
in S. W. corner of the field next S. &
about 20' from fences.
Witnesses. Cen. B.O. 18" N. 30°
Cen. Hick. 13" S. 65°

Department of Engineering.

To see how near to 180° 00' 00" their sum would come. Transit 1641.

Party. Alcibiades Drynoodle.
Antiochus Platitude.
Both read the angles independently.
Each recorded for the other.

angle.

with the ground on the first prominent
n Arbor, Mich., from which a
55° E. 73.3 to its center, and a
35° E. 261.4 " " "

with the ground in the S. E. angle of
rbor, Mich. about 4.0 N. W'ly from the
should be taken.

flush with the ground, on the high ground
of Fireman's Park, Ann Arbor, Mich.

W. 113.6
W. 217.9

A. Platitude.

To p. 30.

From p. 29

1897-10-26

University of Michigan.

Angles of Triangle A. B. C.

At ⊙ A.

Ver. A.	Ver. B.			
16° 20′ 30″	196° 21′ 00″	20′ 45″		
77° 13′ 00″	257° 12′ 45″	12′ 52.″5	12′ 52.″5	
16° 20′ 00″	196° 20′ 00″	20′ 00″	20′ 22.″5	60° 52′ 30″

At ⊙ C.

221° 16′ 30″	41° 16′ 15″	
256° 23′ 00″	76° 24′ 00″	
221° 17′ 00″	41° 16′ 30″	
16′ 45″	16′ 22.″5	
35° 06′ 15″	35° 07′ 37.″5	35° 06′ 56.″25

At ⊙ B

347° 22′ 15″	167° 21′ 45″	
71° 22′ 00″	251° 22′ 30″	
347° 22′ 15″	167° 22′ 30″	
83° 59′ 45″	84° 00′ 45″	
83° 59′ 45″	84° 00′ 00″	
59′ 45″	00′ 22.″5	84° 00′ 03.″75
		179° 59′ 30″
		180° 00′ 00″
		+ 0° 00′ 30″ Error

Department of Engineering.

Ann Arbor, Mich. A. Drynoodle Inst.
A. Platitude Rec.

S. W'ly to ⊙ C.
N. W'ly to ⊙ B.
S. W'ly to ⊙ C.
W'ly Angle.

N'ly to ⊙ B.
N. E'ly to ⊙ A.
N'ly to ⊙ B.

N. E'ly Angle.

S. E'ly to ⊙ A.
S'ly to ⊙ C.
S. E'ly to ⊙ A.

S. E'ly Angle.

A. Platitude.

IV. SURVEY OF A TRIANGLE.

FIELDWORK.

51. Outfit.

Transit.
Measuring set.
Axe, stakes, and nails.

Examine the articles as issued, or be liable for defects found upon their return.

52. Stake out a triangle with sides about 500 ft. long. Estimate their length.

Designate the stakes by A, B, C.

Record a description of each stake, and its general location, under its letter, in the note book. Take four, or more, witnesses to each stake. Record these witnesses with the description of the stake.

⊙A. Is a nail in a stake 1″ x 2″ driven flush with the ground in the S.W. corner of the second field N.W. of John Smith's house on the N.E. side of the South Ypsilanti Road about 1¾ miles S.E'ly from State St. in Ann Arbor, Mich., from which a

Witnesses. Swamp Oak 14″ in diameter, bears N. about 50° W. 8′.45 to its center, and a

Pear tree 6″ bears N. about 25° E. 184′.7 to cen.

Spike in root of Soft Maple 20″ S. 86°? E. 42′.19.

4′.3 W'ly to range of E'ly corner of barn about 10 rods S'ly, and the peak of the N.E'ly gable of the next dwelling S.E'ly from said barn on S.W'ly side of highway, above named.

Similarly for ⊙B and ⊙C.

Read, record, and reduce, the angles of this triangle, following the instructions and form, given above.

Use small marks to sight to,—a nail, a spike, or a pencil.

Measure the sides of this triangle, with the steel tapes.

Record these measurements.

Verify the work by adding the angles, and by the sine equation, $b \sin A = a \sin B$, &c. Record the discrepancies.

IV. TWENTY ROD READINGS

On the Same B. M.

FIELDWORK.

53. Outfit.

Level.
Leveling Rod,—target rod.
Axe, and a stake.
Examine the articles as issued, or be liable for defects found upon their return.

54. Directions.

Set up the level firmly and level it carefully.
Drive the stake 350 or 400 ft., estimated, away from the level, about flush with the ground.
Rodman take leveler's note book.
Rodman hold up the rod on top of the stake.
Set the target as precisely as possible. Be sure the bubble reads level.
Rodman record the reading of the rod in the leveler's book according to the form below, without calling off the same.
Leveler start the leveling screws sufficiently to throw the bubble away from its level reading. Do not disturb the level otherwise.
Level the instrument again carefully.
Take a second rod reading as precisely as possible.
Rodman record the reading as before.
Start the leveling screws again.
Repeat these operations, using the utmost care, until there are twenty rod readings recorded in the leveler's book.
Change places, and do the same work again.
Add the twenty rod readings.
Divide the sum by 20.
Subtract each rod reading from the quotient, or average reading.
Record the discrepancies, each with its proper sign.
Add them. See if their total sum is zero.
This is a device sometimes used to check the average result. It is not a very safe check, as it does not verify the various steps in the process.

University of Michigan.

1909-9-8

Twenty rod readings on the

Both took twenty rod readings.

	Rod.	Discrepancies. +	−
1.	6.398	.00165	
2.	6.407		.00735
3	6.405		.00535
4.	6.397	.00265	
5	6.395	.00465	
6.	6.400		.00035
7	6.402		.00235
8	6.396	.00365	
9	6.398	.00165	
10	6.399	.00065	
11	6.401		.00135
12	6.400		.00035
13	6.398	.00165	
14	6.396	.00365	
15	6.395	.00465	
16	6.399	.00065	
17	6.404		.00435

Department of Enginuering.

same B.M. Level 423.

Party. Bascule Bumpus.
Makepeace Warworm.

Each recorded the other's readings.

Discrepancies.

	Rod	+	−
18	6.401		.00135
19	6.402		.00235
20	6.400		.00035
20	127.993		
	6.39965		
		.02550	.02550

Makepeace Warworm. Rec.

V. READING ANGLES. CLOSING THE HORIZON.

FIELDWORK.

55. Outfit.

Transit.

Axe, and a stake and nail.

Examine the articles as issued, or be liable for defects found upon their return.

56. Directions.

Take the transit to a place commanding a view around the horizon.

Drive the stake flush with the ground and drive the nail in its top.

Set up the transit firmly. Level it carefully.

Select five, or more, objects at distances away of from half a mile to two miles, so as to divide the space around the horizon into five, or more, angles.

Read, and record, each of these angles separately.

Each person read each angle independently.

Do not set the plates to read zero.

For the nearer objects use a joint in the brick work of a chimney, a sash bar in a window, or some similar small object to sight to. At a greater distance the corner board on a house, the post on a porch, the finial on a cupola, or some similar somewhat larger object that can be bisected precisely, make suitable marks to sight to.

Reduce the angles.

Add them. See if the sum equals 360°.

Record the discrepancy.

V. PEG LEVELS. SHORT CIRCUIT.

FIELDWORK.

57. Outfit.

Level.
Leveling Rod.
Axe. Pegs. Piece of chalk.

Examine the articles as issued, or be liable for defects found upon their return.

58. Directions.

To find the difference in elevation between two objects not far apart. Involves three or four settings of the level. Done to learn the process. Follow the form, given below, for the record.

Set up the level firmly, not over 350 ft. away from the place from which the leveling is to proceed, and where it will be convenient to continue towards the place the levels are to run to. Level the instrument carefully.

Take a rod reading with precision on B. M.

Record it in the + S column.

Rodman find a suitable place for a turning point not over 350 ft. from the level and where it will be convenient for continuing the leveling. Such places are tops of stones fast in the ground, tops of curbs, cement, or stone, walks, cross walks, or tops of hydrants. On a large surface like a curb or cross walk mark the place the rod is held up on with chalk, or otherwise, so it cannot be mistaken, and can be found again. If no such place is found, drive a peg in the ground till it stands firm and is nearly flush with the surface. Use the top of this peg for a turning point.

Take a rod reading with precision on T. P. (turning point).

Record it in the — S column on the next line below the last rod reading in the + S column.

Take up the level,—after the record is made, not too quickly.

Set it up not over 350 ft. beyond the T. P. on the way the levels are to go.

University of Michigan.

1909-9-9

Peg Levels. Short circuit

To find the difference in elevation and top of watertable at West Hall,

B.M. to watertable.			Watertable to B.M.	
+S	−S	Peg to Peg.	+S	−S.
6.381				2.234
0.986	11.592	−5.211 +5.208	7.442	1.318
1.114	8.815	−7.829 +7.835	9.153	1.736
11.322	0.516	+0.598 −0.600	1.136	11.323
19.803	0.644	+10.678 −10.683	0.640	16.611
	21.567	−1.764 +1.760	18.371	

1.762 Watertable below B.M.

Department of Engineering.

B. & B. Level 183.

Party Serene Skipper
Active Trimmer

between U. S. Geol. Survey B. M. at Mech. Lab. Univ. of Mich.

Returned on the same pegs.
On B. M.

On W. T.

Active Trimmer.

Take a rod reading with precision on the T. P.
Record it in the + S column on the same line as the last rod reading in the — S column.
Rodman, find, or make, the next T. P.
Take a rod reading on it, as before.
Record this in the — S column on the next line below the last rod reading in the + S column.
Move the level, as before.
Continue the work in this manner until a rod reading is taken on the place to which the levels run and is recorded in the — S column.
Let the level stand.
Continue the record as above outlined, and as per form.
Leveler take the rod. Rodman take the level.
Repeat the rod reading on the place the levels were run to, preparatory to returning on the same pegs.
Record this in the second + S column on the same line as the previous rod reading on the same place in the first — S column.
Repeat the rod reading on the last T. P.
Record this in the second — S column on the next line above the last rod reading in the second + S column.
Move the level.
Continue the work back to the starting place, until a rod reading is taken on the B. M. where the levels began.
Record the successive rod readings in the second + S and — S columns, proceeding up the page as in the form.
Add the rod readings in each + S column.
Add the rod readings in each — S column.
Add, with their signs, each pair of these sums, that is, find the algebraic sum of the rod readings taken on the way out, and of those taken on the way back.
See if these results have opposite signs and are nearly equal. If not, repeat the work and correct the errors. There is no way of finding an error in such work except by repeating the work. A plus result shows the place at the end of the run to be higher, and a minus result, lower, than the starting place.

Add the rod readings, with their signs, in pairs, that were taken at each setting of the level, as + 6.381 and — 11.592, giving — 5.211 as the distance the first T. P. is below the B. M. Enter these sums, with their signs, in columns, beside the rod readings that gave them, both going and returning. For convenient comparison the figures may be arranged as in the form. There may be found greater discrepancies in the figures showing the difference in elevation between the same two T. P's going, and returning, than appears for the entire circuit. In the form, the discrepancy for the circuit is 1.764 — 1.760 = 0.004, while between the first and second T. P.s the discrepancy is 7.835 — 7.829 = 0.006. It may also be noticed that these discrepancies are in opposite directions. Such comparisons show the so-called "Closing error" of a leveled circuit to have only a general value, and that discrepancies in such work are compensating.

If it is impracticable to use the same T. P.s, going and returning, the two lines of levels will have no connection except at their ends and the above comparisons cannot be made.

VI. TRAVERSING.

FIELDWORK.

59. Outfit.

Transit.
Measuring set.
Two line staves.
Axe, stakes, and nails.

Examine the articles as issued, or be liable for defects found upon their return.

60. Directions.

A field with seven sides, and one reentrant angle. No side less than 500 feet. To enclose from 30 to 40 acres.

61. Stake out the field.

Designate the stakes by A, B, C, D, E, F, and G.

Record a description of each stake, and its general location, under its letter, in the note book. Take four, or more, witnesses to each stake. Record these witnesses with description of stake.

62. Forms of record.

Field of seven sides situated between Packard street and the Ann Arbor railroad south of Hill street, and north of the E. & W. ¼ line of Section 32, T. 2 S. R. 6 E. Mer. of Mich. A, B, C, D, E, F, G, designate the vertices of the angles in the boundaries of this field.

⊙ A. Is a nail in a stake driven flush with the ground, standing on the third prominent ridge N. of the Detroit Observatory, Ann Arbor, Mich., from which a

Witnesses. Hickory, 12″ in diameter, bears N. about 55° E., 72′.3 to its center, and a

B. Walnut 27″ bears S. about 35° E. 261′.4 to cen.

Spike in root of Sycamore 32″, S. about 45° W. 47′.13.
Spike E. face of brick wall near S.E. corner of barn, N.W'ly 34′.27.

Field notes of traverse to read from bottom of page upward.

63. Measure the sides.

Measure down hill.

As each measurement is made enter it in the sixth column of the record on the line with the note in the third column, showing in which direction the measurement proceeded. See form of record following.

64. Instrument work.

Set up the transit at any station, as A.

Backsight to G by means of either clamp and slow motion screw, the other clamp being clamped.

Read both plate verniers. Record these readings in the two left hand columns of the field notes at the bottom of the page, with a note in the third column that the pointing is from A to G,—all as shown in the form of notes.

Take another look at the verniers and backsight, to make sure the pointing is exact and the vernier readings correctly recorded.

Release the plate clamp.

Set the line of sight on the mark at B by means of the plate clamp and slow motion screw.

Read both plate verniers. Record these readings in the fourth and fifth columns of the notes on the next line above the last entry, with a note in the third column that the pointing is from A to B.

Release the plate clamp. Set the line of sight again on A G by means of the plate clamp and slow motion screw.

Read both plate verniers. See if these readings agree sufficiently well with those when the first pointing A to G was made. If not, repeat the work till they will. Record these read-

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903-10-29 Traverse Survey of Seven Sid
See fsp. 65 to 70 for records of co

Backsights. Ver. A	Backsights. Ver. B	Points.	Foresights. Ver. A	Foresights. Ver. B.	Distance in feet.
259°44'00"	79°44'30"	E to D	✓		
		E to F	47°36'30"	227°36'00"	600.00
259°44'00"	79°44'30"	E to D			
39°57'30"	219°57'30"	D to C	✓		
		D to E	259°44'00"	79°44'00"	499.91
39°57'00"	219°57'30"	D to C			
348°59'00"	168°59'00"	C to B			
		C to D	39°57'00"	219°57'30"	499.87
348°59'00"	168°59'00"	C to B			
244°17'00"	64°16'30"	B to A			
		B to C	348°59'30"	168°59'00"	500.00
244°17'30"	64°17'00"	B to A			499.92
54°29'30"	234°29'00"	A to G.	✓		
		A to B.	244°17'30"	64°17'00"	
54°29'30"	234°29'00"	A to G			1149.65

Department of Engineering.

d Field.	Party.	Andrews, R. E.
ners.		Lathy, C. B.
Transit B. & B.		Murdock, C. E.
1382.		Shober, M. R.

C. E. Murdock.

University of Michigan

1903-10-29 Traverse Survey of Seven Sided

Backsights		Point-ings.	Foresights.		Distan
Ver A	Ver B		Ver A	Ver B	in feet
184°01'00"	4°01'00"	G to F			
		G to A	234°29'00"	54°29'00"	Closin
184°01'00"	4°01'00"	G to F			
47°36'00"	227°36'00"	F to E			
		F to G	184°01'00"	4°01'00"	499.9
47°36'00"	227°36'00"	F to E			

Department of Engineering.

Field. Party, — p. 71 Transit
B. & B. 1382.

rror + 0° 00' 15"

C. E. Murdock

ings in the two left hand columns of the notes on the line next above the last entry, with a note, in the third column that the pointing is from A to G.

Again direct the telescope to B, and set up a picket behind the eyepiece, facing B,—if pickets are used.

Move the transit and set it up at B.

Set the plate verniers at the same readings they had when the pointing was from A to B,—each vernier at its original reading,—do not exchange them.

Set the line of sight on A, by means of the spindle clamp and slow motion screw.

Read both plate verniers. Record these readings in the first and second columns of the notes, with a note in the third column showing the pointing to be from B to A.

Leave one space blank between these and the last previous entries.

Compare these entries in the first and second columns with the last previous ones in the fourth and fifth columns. If they are not the same, or as nearly so as can be, repeat the setting of the plate verniers and the pointing from B to A, till these records agree.

Look once more at the verniers, and be sure they read correctly. Also notice the pointing and make sure it is exact.

Release the plate clamp.

Set the line of sight on C, by means of the plate clamp and slow motion screw.

Read both plate verniers. Record these readings in the fourth and fifth columns of the notes on the next line above the last entries, with a note in the third column showing the pointing to be from B to C.

Release the plate clamp. Set the line of sight again on B A by means of the plate clamp and slow motion screw.

Read both plate verniers. See if these readings agree sufficiently well with those when the first pointing B to A was made. If not, repeat the work till they will. Record these readings in the two left hand columns of the notes on the line next above the last entry, with a note in the third column that the pointing is from B to A.

Again direct the telescope to C, and set up a picket behind the eyepiece, facing C,—if pickets are used.

Move the transit and set it up at C.

Repeat the same operations there, using first the plate readings obtained when sighting from B to C. Proceed in this way around the field until the transit is set up at G. When the plate readings for the pointing G to A are recorded, they should be the same as the plate readings when the pointing A to G was taken, with the readings exchanged between the verniers. If this is not the case review the work and correct the errors.

In a field with an even number of sides the readings will not be exchanged between the verniers.

VI. PEG LEVELS. LONG CIRCUIT.

FIELDWORK.

65. Outfit.

Level.

Leveling rod.

Axe. Pegs. Piece of chalk.

Examine the articles as issued, or be liable for defects found upon their return.

66. Directions.

Run peg levels from the U. S. eGol. Sur. B. M.—El. 874.976, —in the south door of the Mechanical Laboratory and find the elevation of some other B. M. a mile, or so, away, and involving from 18 to 30 settings of the level, due to the distance, or difference in elevation. Make the record show the closing error, and the discrepancies peg by peg, if practicable. Follow the instructions for peg levels given under V.

VII. COMPUTING AND PLATTING TRAVERSE.

OFFICE WORK.

67. Outfit.

Field notes of traverse survey.

68. Traverse Angles.

Beginning in the central part of the notes, check off either vernier reading for the traverse angle of the side along which the forward pointing was made, that is, in those columns marked "Foresights." Proceeding each way from this traverse angle check off vernier readings, alternately in "Ver. A" column and "Ver. B" column, for the forward pointings along the several lines, till a traverse angle is marked for each side of the survey.

69. Prepare book.

Make eight columns, about an inch and a quarter wide, across the open field note book, using the following headings:
Trav. Ang. Dist. $+s$ $-s$ $+c$ $-c$ x y

70 Enter notes in above form.

Enter in the first column the traverse angles checked off in the field notes, and in the second column on the same line with each traverse angle, the length of the side to which it belongs. Leave a blank above each entry.

71. Compute the traverses, s and c.

$A =$ traverse angle of any side.
$d =$ length of the side A belongs to,—always plus.

Signs of sin. A and cos. A are according to the quadrant in which A ends.

$$\text{Compute } \pm s = d \sin. A.$$
$$\text{and } \pm c = d \cos. A.$$

Sample computation.

s		c
2.528274	337.50	2.528274
9.820774	41° 26′ 30″	9.874847
2.349048		2.403121
+223.38		+253.00

Take out the results to the second decimal place, only.

Enter these values of s and c in their proper columns against the values of d from which they came.

Find Σs and Σc. Both should equal zero.

72. Errors.

In case the difference from zero of Σs and Σc is large, review all the figures from the checking off of the vernier readings, and correct all errors found.

If the difference from zero is still large, review, and verify, the work in the field.

When the errors are found and corrected Σs and Σc will nearly equal zero.

73. Balancing traverses.

Find and correct all errors that can be found, and bring Σs and Σc as nearly to zero as practicable before applying any corrections.

Compute the corrections for any traverse by the following equations:

For the sine traverses,

$$\pm C_s = \frac{\Sigma s}{\Sigma d} d$$

For the cosine traverses,

$$\pm C_c = \frac{\Sigma c}{\Sigma d} d$$

Use the different values of d in succession to obtain the corrections for the traverses of the various sides. Subtract these corrections from the traverses to which they apply, observing all signs.

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1903-10-30 Traverse Survey of Seven Sided
Computations.

	Trav. Dist. Ang.		+ S	− S	+ C
				450.46	
A to B	244°17'15"	499.92		~~450.42~~	
			95.46		
B to C	168°59'15"	500.00	~~95.51~~		
			320.96		383.1
C to D	39°57'15"	499.87	~~321.00~~		~~383.1~~
			491.86		89.1
D to E	79°44'00"	499.91	~~491.91~~		~~89.1~~
			443.05		404.5
E to F	47°36'00"	600.00	~~443.10~~		~~404.5~~
			34.98		498.6
F to G	4°01'00"	499.90	~~35.02~~		~~498.6~~
				935.85	
G to A	234°29'00"	1149.65		~~935.75~~	
			1386.31	1386.31	1375.4
	$\Sigma d = 4249.25$		~~1386.54~~	~~1386.17~~	~~1376.4~~
			+ 0.37 = Σ s		Σ c

Department of Engineering.

Field. Party, — p. 71.

— C	X	Y	
216.88			
~~216.89~~	— 450.46	— 216.88	B
490.77			
~~490.79~~	— 355.00	— 707.65	C
	— 34.04	— 324.52	D
	+ 457.82	— 235.40	E
	+ 900.87	+ 169.16	F
	+ 935.85	+ 667.84	G
667.84			
~~667.87~~	000.00	000.00	A
1375.49			
~~1375.55~~			
— 0.12			

R. E. Andrews.

University of Michigan.

1903-10-30 Traverse Survey of Seven Sides
Computations.

+ Double Areas. $-x_n(c_n + c_{n+1})$	− Double Areas.
	318768.0190
	38212.2000
16075.3900	
	226016.5776
	813701.8188
158308.3860	
74383.7760	1396698.6154
	174383.7760
	2) 1222314.8394
	611157.4197

Department of Engineering.

Field. Party, — p. 71.

	+ Double Areas.	− Double Areas.
$+\frac{1}{2}(S_n + S_{n+1})$		
76992.4000		
		294679.6130
		263776.3464
		220077.8140
80863.5548		
		601637.0208
157855.9548		1380170.7942
		157855.9548
		1222314.8394

square feet

C. B. Lathy.

Enter the corrected values of the traverses in the blank spaces above the traverses as first computed. Draw neat pencil marks through the former values.

Find Σs and Σc anew, using the corrected traverses. They may still not quite equal zero. In this case apply any small remaining errors to the traverses of one or more of those sides the field data for which is most open to suspicion of being erroneous. In case there are no such sides apply the final corrections to the traverses of the longest side, or sides.

By repeating the first corrections a second or even a third time, in the case of some very poor work, and by distributing the small remaining errors as above directed, finally bring Σs and Σc, both to actual zero.

74. Computing coordinates, x and y.

$$x = \Sigma s \qquad y = \Sigma c.$$

Observe all signs carefully.

Find the sum of the sine traverses to the end of each side of the field in succession, for the values of x. Similarly, sum the cosine traverses for the values of y. The last x and the last y must be zero.

75. Prepare book.

Make four columns about two inches wide, two on each page of the open field note book, using the following headings:

$$+D.A. \quad -D.A. \quad +D.A. \quad -D.A.$$

D. A. means double area.

76. Compute *D. A.*

$$\begin{aligned} D.A. &= \Sigma - x_n\,(c_n + c_{n+1}) \\ &= \Sigma + y_n\,(s_n + s_{n+1}) \\ &= \Sigma - c_n\,(x_{n-1} + x_n) \\ &= \Sigma + s_n\,(y_{n-1} + y_n) \\ &= \Sigma - x_n\,(y_{n+1} - y_{n-1}) \\ &= \Sigma + y_n\,(x_{n+1} - x_{n-1}) \end{aligned}$$

Observe all signs carefully.

Use two of these forms.

Enter the results obtained by the two different forms, on the two different pages, the + results in the + *D. A.* columns and the — results in the — *D. A.* columns.

Do not use logarithms in these computations of *D. A.*, but natural numbers. Take both decimals in all the values of *s, c, x,* and *y,* thus giving four decimals in each product.

Sum the products on each page for the double area of the field. These sums must be identical out to the last right hand figure.

Divide the double area by 2 to get the area of the field. Reduce the area to acres.

77. Directions. Platting.

Each person make a plat of the traversed field, on cross ruled paper. See Sec. 10.

Select the origin and axes of coördinates. Assume a scale.

Count off the coördinates of A, B, C, &c., and mark them on the paper.

Measure A to B, B to C, &c., to scale on the paper. See if these measures agree with those made on the ground. If not, correct the platting.

Join A and B, B and C, &c., by plain black lines, not too broad.

Complete the plat according to the instructions in Sec. 10.

Fasten the plat in the field note book to the stub of a cut out leaf.

The axis of Y is the reference line and the + direction is 0° for the traverse angles. If the plate readings that were not checked had been taken as the traverse angles the 0° would have been in the opposite direction.

COMPUTATIONS RELATI

SYMBOLIC

TRAV ANGLE	DIST.	TRAVERSES		COORDINATES	
A	d	$s = d \sin A$	$c = d \cos A$	$X = \Sigma s$	$y = \Sigma c$
A_1	d_1	$s_1 = d_1 \sin A_1$	$c_1 = d_1 \cos A_1$	$X_1 = s_1$	$y_1 = c_1$
A_2	d_2	$s_2 = d_2 \sin A_2$	$c_2 = d_2 \cos A_2$	$X_2 = X_1 + s_2$	$y_2 = y_1 + c_2$
A_3	d_3	$s_3 = d_3 \sin A_3$	$c_3 = d_3 \cos A_3$	$X_3 = X_2 + s_3$	$y_3 = y_2 + c_3$
A_4	d_4	$s_4 = d_4 \sin A_4$	$c_4 = d_4 \cos A_4$	$X_4 = X_3 + s_4$	$y_4 = y_3 + c_4$
etc	etc	etc	etc	etc.	etc.
to	to	to	to	to	to
A_m	d_m	$s_m = d_m \sin A_m$	$c_m = d_m \cos A_m$	$X_m = X_{m-1} + s_m$	$y_m = y_{m-1} + s$
		When corrected		If $X_m = a$	If $y_m = b$
		$\Sigma s = 0$	$\Sigma C = 0$	$X = a - \Sigma s$	$y = b - \Sigma$
		Observe all signs		Plat is made by coordinates	

G TO A CLOSED SURVEY.——

L TABLE

DOUBLE AREA	DOUBLE AREA	DOUBLE AREA	DOUBLE AREA	DOUBLE AREA	DOUBLE AREA
$X_n(c_n + c_{n+1})$	$y_n(s_n + s_{n+1})$	$-c_n(x_1 + x_n)$	$s(y_{n-1} + y_n)$	$-x_n(y_{n+1} - y_{n-1})$	$y_n(x_{n+1} - x_{n-1})$
$X_1(c_1 + c_2$	$y_1(s_1 + s_2)$	$-c_1(x_m + x_1)$	$s_1(y_m + y_1)$	$-x_1(y_2 - y_m)$	$y_1(x_2 - x_m)$
$x_2(c_2 + c_3)$	$y_2(s_2 + s_3)$	$-c_2(x_1 + x_2)$	$s_2(y_1 + y_2)$	$-x_2(y_3 - y_1)$	$y_2(x_3 - x_1)$
$x_3(c_3 + c_4)$	$y_3(s_3 + s_4)$	$-c_3(x_2 + x_3)$	$s_3(y_2 + y_3)$	$-x_3(y_4 - y_2)$	$y_3(x_4 - x_2)$
$x_4(c_4 + c_5)$	$y_4(s_4 + s_5)$	$-c_4(x_3 + x_4)$	$s_4(y_3 + y_4)$	$-x_4\ y_5 - y_3)$	$y_4(x_5 - x_3)$
etc.	etc	etc	etc	etc.	etc.
to	to	to	to	to	to
$(c_m + c_1)$	$y_m(s_m + s_1)$	$-c_m(x_{m-1} + x_m$	$s_m(y_{m-1} + y_m)$	$-x_m(y_1 - y_{m-1})$	$y_m(x_1 - x_{m-1})$

Sum of entries in any double area column equals double area of piece. Use two columns.

VII. PROFILE LEVELING.

FIELD WORK. PARTY OF FOUR PERSONS.

78. Outfit.

Transit.
Measuring set.
Two line staves.
Axe. 30 or 35 stakes. 3 or 4 plugs. Nails. Marking chalk.
Levels,—2.
Leveling rods, 2.
Axe. Pegs,—about 50.
Examine the articles as issued, or be liable for defects found upon their return.

79. Directions.

On rough ground select a place where a straight line about 3000 ft. long can be laid out, and either end of it seen from the other.
Drive a plug with nail in same, to mark the end of the line where the measuring is to begin,—or zero end.
Witness this plug. Record full information about it.
Mark a stake with the line mark and the numeral 0.
Drive this stake about a foot to the right of the plug, as the line will run, with the marks facing away from the other end of the line.
Set up the transit over the nail in this plug.
Drive another plug with nail to mark the line near its other end.
Witness this plug. Record full information about it.
Hold up a line staff on the nail in this plug.
Set the line of sight of the transit on the line staff.
Take away the line staff.
Set a picket in line beyond the distant plug,—or any suitable mark to keep the line by,—or find some object in exact line to be used to sight to for line.

Hold up the line staff again, on the nail in the distant plug.

See if the cross wire bisects it exactly. If not, review the work and correct the errors, till sure the distant mark is in exact line.

Call back the line staff.

Watch the transit while laying out the line; by frequent references to the distant mark for line; by looking at the plate levels to see that the bubbles read level, especially the one parallel to the transit axis; and occasionally examining the plumb bob to see if it keeps exactly over the nail in the plug.

Measure 100 ft. from the nail under the transit in the direction the line is to go.

Get line at the end of the 100 ft. with the line staff.

Mark a stake with the line mark and the numeral 1.

Drive this stake at the end of the 100 ft. on the line, and with the marks facing the plug where the transit stands.

Drive the stake so it stands plumb and is firmly set.

Test it for line and distance. Correct it for either, or both, by pounding the ground close beside the stake, but leave it plumb and firm. Move it if necessary.

Measure again and mark 100 ft. on top of the stake.

Get line on the stake at the end of the 100 ft.

Drive a small nail in the top of the stake to mark station 1 at just 100 ft. from station 0,—the nail under the transit, —and in line.

Measure on 100 ft. beyond 1 and set and mark 2 with the same care and precautions used at 1.

Continue setting stakes in this manner until the whole line is marked or some place is reached where it becomes necessary to move up the transit in order to see to give line for the stakes.

Choose a place for a new transit plug from which the distant line mark can be seen and also the succeeding stakes to be set.

Look over the transit and see that it is over the nail, is level, and the line of sight is on the distant mark.

Give line for the new plug.

While the plug is being driven look the transit over again for position, level, and line, and be ready to give line at once.

Get line on the plug with the line staff.

Mark the place.

Take away the line staff.

See that the line of sight strikes the distant mark.

If not, review the work and correct the errors until it will.

Signal "All right."

Drive a nail, not quite down, at the mark on the plug.

Call up the transit.

While the transit is coming, measure the plus from the preceding stake and record this plus and any other information about this plug.

Mark a stake with the line mark and station number and plus for this plug, and drive it about a foot to the right of the plug.

Set up the transit over the nail in the new plug.

Set its line of sight on the distant mark.

Measure 100 ft. from the last regular station set, not the transit plug, if at a plus, and continue setting stakes, as before.

Continue marking the line somewhat beyond the last distinctive depression, or rise, on the line, even if it is a few hundred feet more than 3000 ft. long.

This is the manner of marking what is called a "Located line" in Leveling and Earthwork.

Divide into parties of two persons.

Find, or make, a B. M. at each end of the line.

Record full descriptions of these benches.

Find, by peg levels, the elevation of one of them, say the one at the zero end of the line, or assume an elevation for it.

With one of the levels begin leveling from the B. M. at the zero end of the line, following the instructions given in Leveling and Earthwork in sections 1 to 13. Section 10 gives special instructions about Location Levels, such as these should be.

With the other level begin leveling from the B. M. at the other end of the line following the same instructions except omitting all elevations.

When the two levelers meet, the leveler from the far end of the line take a precise rod reading on some T. P. or B. M. whose elevation has been found by the party that began at the zero end of the line.

Party No. 2 work out all of their elevations.

Both parties continue leveling till each has covered the whole line and all the benches.

Both parties run "Check Levels" between all the benches,—see section 13 of Leveling and Earthwork.

Taking the B. M. at the zero end of the line to be correct, both parties reduce the corrected elevations for all the benches.

Take the half sum of these elevations of bench marks found by each party as their corrected elevations.

Correct all the elevations of stations, plusses, and turning points, between benches to conform to the corrected elevations of the benches.

Agree upon the corrected elevations of every place where a rod reading was taken. If unable to agree at first, both repeat enough of the work on the ground to reach an agreement.

The result will be the corrected levels for this line from which the profile is to be made.

Continuous Level Notes.

Juniper Hill and Spring Grove R.R. Line

+S.	H.I.	−S.	Elevations	Objects	
			104.632	B.M.	Root
4.785	109.417				
		3.16	106.26	Sta 0	Line
		4.78	104.64	1	
		6.32	103.10	2	
		5.46	103.96	+40	
		8.27	101.15	3	
		6.24	103.18	+25	
		5.931	103.486	+45	T.P.
6.421	109.907				
		6.21	103.70	4	
		7.42	102.39	5	
		10.68	99.23	+60	Bend
		9.31	100.60	6	
		8.24	101.68	7	
		10.432	99.475	B.M.	Root
		7.28	102.63	8	
		6.38	103.53	9	
		7.84	102.07	+40	Center
		10.366	99.542	O.K. 10	T.P.
0.861	100.403				
		8.26	92.14	+75	Top of

Leveller's Book.

Location. 1890-7-14.

Maple Bough Township.

F. Walker, leveller. S. Poke, rodman.

16" Beech Left of 748+75, Lone B.

Sta 745+67.3 Lone B.

	Proof	
	+ S	- S
	4.785	
	6.421	5.931
		10.365
	104.632	99.542
	115.838	115.838

Placid River (200' wide) 275' L.

14" Hard Maple 80' R. of 7+70 where line leaves woo

Highway.

bank of small stream, running to R.

-S	J. H. I.	H. -S.	℄ El.	S. Az.	G.
	100.403				
		10.4	90.00	+76	Bottom
		11.3	89.1	+78	Center
		10.6	89.8	+81	Bottom
		8.42	91.98	+83	Top of
		7.84	92.56	11	
		8.32	92.08	+30	
		11.170	89.233	+50	T. P.
0.417	89.650				
		10.978	78.672		T.P.
0.396	79.068				
		9.284	69.774	+70	T.P.
		8.437	70.631	B.M.	Root of
		10.496	68.572	+95	Edge of
		11.1	68.0	12	Bottom
Round soft marsh.			64.0	13	4.6 Dept
4.633		4.557	60.7	14	7.9 "
3.741		3.817	57.9	15	10.7 "
4.692		4.713	60.5	16	8.1 "
13.066		13.087	62.0	17	6.6 "
	79.047	0.021	66.0	18	2.6 "
		10.477	68.570	+48	Edge of
		9.20	69.8	+60	Bottom
		0.368	78.679	0.K.B.M.	X ona

R. R. Line I.

F. Walker, Cor. S. Poke, Rod. 1890-7-14.

	Proof	
ank.		
hannel. Water 1.9 deep.	+ S.	- S
ank.	0.861	
ank.	0.417	11.170
	0.396	10.978
	13.066	13.087
op of bank of Crystal Lake.		0.368
	99.542	78.679
	114.282	114.282

Bottom of bank.
7" Elev 75' L of 11+75.
ater. Water level.
ake. Sand. Firm.
f water
"
"
"
"
"
ater. Water level.
l bank.
6 ft boulder, 2 ft out of ground, 80' R. Sta. 19.

	J.	H.		S.	G.
+ S.	H. I.	− S.	El.	Ob.	
			78.679	B.M.	
9.433	88.112				
		7.83	80.28	19	
		4.69	83.42	+35	Top of
		6.657	81.455	B.M.	Root of
		3.73	84.38	+75	
		0.896	87.216	20	T. P.
8.472	95.688				
		7.22	88.47	21	Inscrip
		5.72	89.97	22	
		5.21	90.48	+30	
		4.32	91.37	+80	
		6.61	89.08	23	
		7.51	88.18	+40	
		5.66	90.03	+55	
		3.97	91.72	24	
		0.000	95.688	+45	T.P. P
10.661	106.349				
		6.64	99.71	+66	
		4.73	101.62	25	
		3.627	102.722	B.M.	Top of
		3.07	103.28	+12	
		0.318	106.031	+35	T. P.
11.014	117.045	0.K.			

R. R. Line L.

F. Walker, Leav. S. Poke, Rod. 1890-7-14.

	Proof.	
	+S	-S
bank. Crystal Lake.	9.433	
10" Red Oak, 75 L. 19+50.	8.472	0.896
	10.661	0.000
	11.014	0.318
	78.679	117.045
of corn field.	118.259	118.259

driven to elevation of cross wire.

T. stone for S. E. cor. brick dwelling, 200' R Sta. 25.

	J.	H.	H	S.	G.
+S	H. I	−S.	Bl.	Ob.	
	117.045				
		7.62	109.42	+55	
		4.71	112.34	26	
		1.42	115.63	+55	
		0.000	117.045	Peg	T. P.
11.026	128.071				
		10.79	117.28	27.	
		10.07	118.00	+ 15.	
		7.10	120.97	+ 40.	
		3.60	124.47	+ 60.	
		1.80	126.27	+ 65.	
		1.01	127.06	28	
		0.000	128.071	Peg	T. P.
11.262	139.333				
		10.47	128.86	+ 25	
		8.66	130.67	29	
		3.71	135.62	+ 90	
		3.61	135.72	30	
		3.02	136.31	+ 33	
		1.83	137.50	+ 50	
		1.80	137.53	+ 70	
		2.11	137.22	31	
		2.15	137.18	+ 55	
		1.978	137.355	B.M.	Top of

0.1K.

R. R. Line L.
F. Walker, Lev. S. Poke, Rod. 1890-7-14.

	Proof.	
	+ s.	− s.
	11.026	0.000
Driven to elevation of cross wire.	11.262	0.000
		1.974
	117.045	137.355
	139.333	139.329

Driven to elevation of cross wire.

Summit.

cap stone (S.W. cor.), bridge seat, E. end highway bridge over Roaring Creek, about 200 ft W. of J. Smith's house

+S.	J. H. I.	H. -S.	of El.	S. Ob.	G.
0.K.	139.333				
		3.25	136.08	32	
		5.14	134.14	+70	
		4.96	134.37	33	
		4.02	135.31	+62	
		5.23	134.10	34	
		7.51	131.82	+60	
Boston Rod.		11.17	128.16	+80	
+6.100		10.307	129.026		T.P.
-6.627		11.40	127.93	35	
-0.527	128.499				
		2.23	126.27	+70	
		4.64	123.86	+75	
		6.23	122.27	36	
		8.16	120.34	+50	
		9.63	118.87	37	
		9.281	119.218	B.M.	Root
0.371	119.589				
		11.62	117.97	+18	
		10.755	108.834	+70	T.P.
0.363	109.197	0.K.			
		1.08	108.12	38	
		4.12	105.08	39	
		4.17	105.03	+45	

R. R. Line L.

1890-7-14

Transit ⊙ in fence at N. E. side of cornfield. Centre: brush pasture

	Proof	
Top of stake at Sta. 35.	+ S	− S
	139.333	10.307
		0.527
	0.371	9.281
	0.363	10.755
		109.197
	140.067	140.067

18" Rock Elm, 80' L. of 36+50.

	J.	H.	ℱ	S.	G.
+ S	H. I.	− S.	El.	Ch.	
	109.197 O.K.				
		2.71	106.49	40	
		2.02	107.18	41	
		1.24	107.96	+ 60	
		1.44	107.76	42	
		0.973	108.224 O.K.	B.M.	Root of

End of these levels.

Continuation of above levels.

			108.224	B.M. above.	
0.741	108.965				
		2.58	106.48	40	
		1.76	107.20	41	
		1.16	107.80	42	
		2.80	106.16	+ 35	
		6.68	102.28	+ 55	
		9.82	99.14	+ 80	
		11.424	97.541	43	T. P.
0.749	98.290				
		6.13	92.16	+ 25	
		10.31	87.98	+ 50	
		11.723	86.567 O.K.	+ 60	T. P.

R. R. Line L.
F. Walker, Lev. S. Pohe, Rod. 1890-7-14.

Proof.

	+ s	- s
	109.197	0.973
		108.224
v. Pine 38", 75ft R. of 42.	109.197	109.197

S. Eaje, Lev. S. Toe, Rod. Lev, - Blunt, 149.
1898-6-1

Proof.

	+ s	- s
	108.224	
	0.741	
	0.749	11.424
		11.723
Brow of steep decent		86.567
	109.714	109.714

+S	J. H. I.	H. −S.	f El.	S. Cl.	G.
			80.567	+60	T. P
0.521	87.088				
		11.682	75.406	+85	T. P.
0.674	76.080				
		8.21	67.87	44	
		11.593	64.487	+30	B. M.
0.479	64.966				
− 6.740		8.21	56.76	+35	
+ 6.272		11.462	53.504		T. P.
−0.468 N.G. Rod.	53.036		1.50 52.00	+50	
− 6.740		10.335	42.701	+70	B. M.
+ 0.776					
− 5.964	36.737				
		7.01	29.73	45	
		11.630	25.107		B. M.
0.652	25.759				
		2.34	23.42	+15	
		5.121	20.638	+35	T. P.
0.499	21.137				
		11.311	9.826	+50	T. P.
0.501	10.317				
		5.390	4.937	0.K. B. M.	
		11.483	− 1.156	+85	T. P.
0.636	− 0.520 0.K.				

R. R. Line L

S. Eye, Lev. S. Toe, Rod. Lev. – Blunt 149.

1898-6-1.

on top of step in face of ledge of syenite on line.

	Proof. +S	−S
Top of stake.	4.937	
	5.390	
Edge of shelf of rock, on line.	0.636	11.483
	0.520	
	11.483	11.483

Top of ledge, 65 ft L. of Sta. 45. Prominent projecti

Proof +S	−S
	11.652
	11.593
	11.462
	0.468
	10.335
	5.964
0.652	11.630
0.499	5.121
0.501	11.311
	5.390
	4.937
89.567	89.893
0.521	
0.674	
0.479	
89.893	

Root of twisted white pine 1800 ft L. of 45+50. N. oth pine near.

	J.	H.	ϕ	S.	S.
+S	H. I.	−S.	El.	Cl.	
	− 0.520				
		10.87	− 11.39	46	
		11.326	− 11.846	+ 10	T. P.
0.577	−11.269				
			0.K.		
		3492	− 14.761	B. M.	
		11.333	− 22.602	+ 50	T. P.
0.482	−22.120				
		11.510	−33.630	+ 75	T. P.
0.431	−33.199				
			0.K.		
		2.277	− 35.476	B. M.	
		3.33	− 36.53	47	
		4.12	− 37.32	+ 20	
		5.10	−38.30	+ 80	
Troy Rod		3.02	− 36.22	48	
Upper target.		2.11	−35.31	+ 45	
0.615		1.06	−34.26	49	
0.778		0.782	− 33.981		T. P. To
−0.163	−34.144	0.K.		1.40	
			− 35.38	50	
		3.11	− 37.25	+ 60	
		6.26	− 40.40	51	
		9.87	− 44.01	52	
		10.16	− 44.30	53	
		10.04	− 44.18	+ 40	
		7.74	− 41.88	54	

R. R. Line L.

S. Leye, Lev. S. Tie, Rod. Lev.-Blunt, 149.

1898-6-1

large
on step on side of detatched fragment of rock 15 ft thick, near central part, about 2 ft above ground, on side next to spring which is 75 ft L. of 46 + 25.

on step of limestone ledge, in place, about 4 ft above ground, 75 R. of 46+75.

Proof.

+ S	- S
	0.520
0.577	11.326
14.761	3.492
of stake at Sta. 50.	
15.338	15.338

Proof.

+ S	- S
0.782	33.981
35.476	2.277
36.258	36.258

Proof.

+ S	- S
	0.520
0.577	11.326
0.482	11.333
0.431	11.510
	0.782
	0.163
34.144	
35.634	35.634

+S.	J. H. I. −34.144	K. −S.	L El.	S Ob.	G.
		6.06	− 40.20	+ 65	
		5.91	− 40.05	55	
	New El.	0.222	− 34.366	B. M.	
			0.14.		
Line C. El.	from Line C Datum.	4.27	− 38.51	55 + 37.6 =	
712.90	712.70	3.16	− 37.30	269 C.	
712.82	710.64	5.22	− 39.36	270 C.	
709.87	709.75	6.11	− 40.25	271 C.	
707.33	707.17	8.69	− 42.83	272 C.	
708.25	708.09	7.77	− 41.91	273 C.	

Error above B. M. to B. M. on Line C Roo

0.222	34.366
3.926	8.471
4.781	2.216
1.466	5.311
	9.987
750.000	
	700.219.
760.395	760.570
+ 0.175	
760.570	760.570.

Datum for Line L. al

El. B. M. Line C al

Apparent error of the

R. R. Line L.

S. Eye, Lev S. Tel, Rod Lev. — Blunt, 149

1894-6-1

on projection of limestone ledge, in place, about 10 ft above ground, and 150 ft R. of 55+50.

271+59.3 of Line C

	Proof.
+ S	− S
	34.144
34.366	0.222.
34.366	34.366

of 40" Sycamore 70 ft L of 245+60 C. on L. bank of Clam Creek.

ve datum for Line C.
ve noted.

levels.

S. Eye, Leveller.

Continuous Level Notes
Juniper Hill and Sunny Grove R. R.

+S.	H. I	-S.	El.	Ch.	
			104.632	B.M.	Root of
4.785	109.417				
		5.931	103.486	3+45	T.P.
6.421	109.907				
		10.432	99.475	0.K. B.M.	Root of
		10 365	99.542		T.P.
0.861	100.403				
		11.170	89.233	11+50	T.P.
0.417	89.650				
		10.978	78.672		T.P.
0.396	79.06				
		9.294	69.774	11+70	T.P.
		8.437	70.631	O.K. B.M.	Root of
		10.496	68.572	11+95	Edge of

Round soft marsh

4.633	4.557
3.741	3.817
4.692	4.713
13.066	13 087

	79.047	0.021			
		10.477	68.570	18+48.	Edge of
		0.368	78.679	B.M.	X on c
			0.K.		

Rodman's Book.

Line L. Location. 1890-7-14.

Maple Bough Township.

T. Walker, Leveller S. Pohe, rodsman.

16" Beech, 65 ft Left of 748+75, Line B

14" Hard Maple, 80 ft R. of 7+70 where line leaves woods

Proof 104.63		Proof. 99.475	
4.785		10.432	
6.421	5.931	0.861	10.365
	10.432	0.417	11.170
	99.475	0.396	10.978
115.838	115.838		8.437
			70.631
27" Elm 75' L. of 11+75.		111.581	111.581

water in Crystal Lake Water level

Proof	-S	
	4.557	
	3.817	
	4.713	
	0.368	
	13.679	
	92.134	
+S		
79.068		
4.633		
3.741		
4.692		
92.134		

water in Crystal Lake Water level.

6' boulder, 2' out of ground, 80 R. of Sta. 19.

+ S	J. H.I.	H. − S.	℄ ℓ.	S. ℄.	G.	
			78.679			
9.433	88.112					
		6.657	81.455	0.K.	B.M.	Root of
		0.896	87.216		20	T.P
8.472	95.688					
		0.000	95.688		24+45	T.P Peg
10.661	106.349					
		3.627	102.722	0.K.	B.M.	Top of W
		0.318	106.031		25+35	T.P
11.014	117.045					
		0.000	117.045		Peg	T.P. Dru
11.026	128.071					
		0.000	128.071		Peg	T.P.
11.262	139.333					
		1.978	137.355	0.K.	B.M	Top of c E. and ing Cri house
		10.307	129.026		35	T.P. To
−0.527	128.499					
		9.281	119.218	0.K.	B.M.	Root of
0.371	119.589					
		10.755	108.834		37+70	T.P.
0.363	109.197					

R. R. Line L

F. Walker, Levr. S. Poke, Rod. 1890-7-14

Proofs

		+ s	- s
10" Red Oak 75' L.	19+50	78.679	
		9.433	6.657
			81.455
driven to level of cross wire		88.112	88.112
T. stone for S. E. cor. brick dwelling, 200' R. Sta. 25.		81.455	
		6.657	
		8.472	0.896
on to level of cross wire		10.661	0.000
			3.627
			102.722
		107.245	107.245
p stone (S.W. cor.) bridge seat, highway bridge, over Roar- about 800' W. of J Smith's		102.722	
		3.627	
		11.014	0.318
of stake.		11.026	0.000
		11.262	0.000
18" Rock Elm, 80' L	36+50		1.978
			137.355
		139.651	139.651

	J.	H	f	S.	G
+S	H I	-S.	El	Al	

109.197

0 973 108.2240.K B.M. Root of

End of these levels

This line was continued by S. Eye

R R. Line L
F. Walker, Cor. S. Pahe. Rod 1890-7-14

8" White Pine, 75' R. Sta. 42.

Proof		Proof	
+ S	− S	+ S	− S
119.218		137.355	10.307
0.371		1.978	0.527
0.363	10.755		9.281
	0.973		119.218
	108.224	139.333	139.333
119.952	119.952		

found S. Toe in 1898 See next page

	J.	H.	ϕ	S.	G.
+ S.	H. I.	− S.	El.	Cl.	
			108.224	B. M.	f. 42.
-0.741	108.965				
		11.424	97.541	43	T. P.
0.749	98.290				
		11.723	86.567	43+60	T. P.
0.521	87.088				
		11.682	75.406	43+85	T. P.
0.674	76.080				
		11.593	64.487	44+30	B. M. ×
			0.1K.		
0.479	64.966				
−6.740		11.462	53.504		T. P.
+6.272					
−0.468	53.036				
−6.740		10.335	42.701	44+70	B. M ×
			0.1K.		
+0.776					
−5.964	36.737				
		11.630	25.107	B. M.	× top
			0.1K.		
0.652	25.759				
		5.121	20.638	45+35	T. P.
0.499	21.137				
		11.311	9.826	45+50	T. P.
0.501	10.327				
		5.390	4.937	0.K. B. M.	Root
		11.483	− 1.156	45+85	T. P.
			0.1K.		

R. R. Line L.

S. Eye. Lev. S. Tel. Rod. Lev. – B.M. 149

1898-6-1.

	+S.	Proofs.	–S.
Brow of steep descent.	108.224		
	0.741		
	0.749		11.424
	0.521		11.723
	0.674		11.682
			11.593
Top of step in syenite ledge			64.487
on line.	110.909		110.909

Proof –S
+S 25.107 0.652 0.499 5.121 0.501 11.311 5.390 4.937 26.759 26.759

Top of stake.

64.487
0.479

Ledge of shelf of rock, on line. 11.462
0.468
10.335
42.701
64.966

Ledge, 65' L of Sta. 45.
Prominent projection. 64.966

+S	Proof	–S		
4.937		11.483	42.701	5.964
5.390		– 1.156		11.630
10.327		10.327		25.107
				42.701

Twisted white pine 100' L. 42.701
45+50. No other pine near.

	J.	H.	G	S.	G.	
+S	H.I.	−S.	El.	Ch.		
			−1.156			T.P. las
0.636	−0.520					
		11.326	−11.846	46+10		T.P.
0.577	−11.269					
		3.492	−14.761	O.K.	B.M.	× on st
		11.333	−22.602	46+50		T.P.
0.482	−22.120					
		11.510	−33.630	46+75		T.P.
0.431	−33.199					
		2.277	−35.476	O.K.	B.M.	× on st
0.615						
0.778		0.782	−33.981			T.P.
−0.163	−34.144					
		0.222	−34.366	O.K.	B.M.	× on fou

For connection with B.M. 2 in C. au

R. R. Line L.

S. Eye. Lev. S. Tol. Rod. Lev. — Blunt 149.

Page. 1898-C-1.

	+S	Proofs.	−S
	0.636		1.156
	0.577		11.326
h on side of large detach-	14.761		3.492
d fragment of rock, 15'	15.974		15.974
luck, near middle, about			
' above ground on side	3.492		14.761
next to spring which is	0.482		11.333
5' L. 46+25.	0.431		11.510
of limestone ledge, about	35.476		2.277
' above ground, 75' R. of	39.881		39.881
46+75.			
Top of stake. Sta. 50.	2.277		35.476
			0.782
ection of limestone ledge,			0.163
bout 10' above ground, 150'	34.366		0.222
R. of 55+50.	36.643		36.643

next page.

J. H. of S. G.

Connection of B. M. 150' R. Sta. 56
B. M. 70' L. Sta. 24

+S	-S.	
0.222	34.366	B. M. Line L. p. 44.
3.926	8.471	
4.781	2.216	
1.466	5.311	
	9.987	
	700.219	El. B.M. Line C. Root of 40"

750.000 Datum for Line L. above datum

760.395 760.570

+0.175 Apparent error.

760.570 760.570

R. R. Line L.

S. Eye. Lev. S. Tol. Rod. Lev. – Blunt 149.

1898-6-1.

50 L ine L, with
+60 L ine C.

Sycamore 70' L. 245+60 C. on L. bank of
Clam Creek.
for Line C.

S. Tol, Rodman.

VIII. PROFILE AND GRADE LINE.

OFFICE WORK.

Each person prepare a profile of the 3000 ft. line of levels.

With advice of teachers, each person fix upon a grade line on profile and work out all elevations of grade, including vertical curves.

Follow the instructions in sections 14 to 22 of Leveling and Earthwork.

VIII. STAKING OUT A GRADE.

80. Information.

If the last mentioned survey, profile, and grade line, were for a railway, highway, or similar consturction, follow Leveling and Earthwork, from section 23 on.

For a canal the work of staking out is similar to that for a railway but the cross sections may be more extended, especially where the canal is enclosed by banks, or where the spoil banks are staked out. However no additional principles are involved more than are given in Leveling and Earthwork.

In making surveys for any excavation over a considerable area, as for a large building, an artificial pond, or for grading, follow the instructions for Borrow Pits given in sections 41 and 45 in Leveling and Earthwork. For filling a piece of ground the work is similar. Stakes, or poles, should be set over the area to be filled, as needed, with tops sufficiently above the finished grade to allow for settlement, see Sec. 57 in Leveling and Earthwork.

A survey for a dam, or similar structure, involves a contour map of the site, as well as a survey similar to that for a railway for a short distance, namely, along the dam itself. If an earth, or rock fill, dam, is to be built the slope on the upstream side may be as flat as 1 on 3, while the slope on the face may be 1 on 2. The whole site for the dam should be covered by borings close enough and carried deep enough, not only to reveal suitable materials for supporting the dam and that will hold back the water from beneath it, but also to reveal any pockets there may be of materials that may prove dangerous. The borings may need to be extended much beyond the site of the dam itself. Frequently, not enough borings are made. This is true for any heavy structure. Such should not be undertaken until the knowledge of the materials below ground is as complete, and as trustworthy, as the knowledge of those on the surface. The borings may have to be as close as 5 ft. by 5 ft., in extreme cases. Borings should be surveyed and mapped. Then profiles of any materials below the surface can be made out and grades, or sub-grades, fixed upon. In the case of the dam, the contour survey and map may be extended up stream as far as the pond will reach to give the pondage.

For a heavy building, the remarks about borings apply.

The same is true for chimneys, towers, bridge abutments or piers, and any similar structure.

Men do not always remember that the load on any structure, as well as the weight of the structure itself, must at last rest on the ground, and that the ground will not in all instances carry "anything." Still more frequently is it forgotten, or disregarded, that the load on each square foot of the materials beneath a structure should be proportioned to the carrying capacity of those materials, if uniform settlement is to be expected. Especially is this true in buildings where footings beneath posts and piers are made too large for those under the walls. The walls settle more than the piers, floors go out of level, and machines and shafting are thrown out of level. All this may require the

various materials upon which a structure of considerable extent is to rest to be uncovered so as to be examined by the engineer and perhaps tests made by applying actual loads to ascertain the amounts and rates of settlement.

In staking out a grade, set the stakes where they will be convenient for reference by the workmen, where they will not be dug up or covered, where they will stand firm, and be secure from disturbance. The same stakes can sometimes be used for both line and grade, as the "Track centers" on a railway, or those set for a ditch or pipe trench.

On any kind of a ditch, or pipe trench, decide upon which side of it the excavated materials shall be placed, so as to leave the other side clear, for access of men, for materials, and for any work that may be required. Fix upon a berm, or the width of the space, between the excavated materials and the side of the ditch, or trench. The berm will depend upon the nature of the materials to be moved, the depth of the digging, the side slope of the work, the weather to be expected, and whether curbing is to be used, or not. Set the grade stakes within this berm,—near its outer edge, if practicable. If the same stakes are used for both line and grade the transit work and leveling must go on together. Decide upon a distance between the center line of the work as marked on the ground, and a line parallel thereto where stakes are to be set by the transit with nails in their tops to mark this parallel line for the use of the workmen. Make this distance even feet, or some simple number, whenever practicable. Give the workmen sticks cut to this distance. This distance may have to be different on different parts of the work.

VIII. STAKING OUT A GRADE.

FIELD WORK. PARTY OF FOUR.

81. Outfit.

Transit.
Measuring set.
Line staff.
Axe. 2″ x 2″ stakes. ⅞″ x 2″ stakes. Nails. Marking chalk.
Level.
Leveling rod.
Axe. Pegs.

Examine the articles as issued, or be liable for defects found upon their return.

82. Directions.

A tile drain, a pipe trench, a ditch, or a walk.

Stakes to be set for both line and grade.

Square out a line with the transit from the center line at some station, or transit plug, on it.

Drive a 2″ x 2″ stake on this squared out line at the distance of the parallel line from the center line.

Drive this stake till it stands plumb and firm.

Drive a small nail in the top of the stake at exact line and distance.

Mark this stake with the number of the transit point, or mark another ⅞″ x 2″ stake with this number and drive it about a foot to the right of the first.

Set another 2″ x 2″ stake, measured, lined, and marked, in the same way from some other station or transit plug on the center line.

Run, measure, and mark, with 2″ x 2″ stakes and nails, giving the stakes the same numbers as the stations on the center line opposite which they stand, a line parallel to the center line, based on the two stakes and nails first set.

Check the measurement from one of these stakes first set, by measuring the closing distance to the other. If the measurement is not near enough correct, review the work and correct the errors.

Set up the level. Find H. I. by taking a rod reading on a B. M.

Decide how high above grade the top of any 2″ x 2″ stake on the line parallel to the center line shall be.

Add this height to the elevation of grade at that place.

Subtract this sum from H. I. for rod reading on the 2″ x 2″ stake.

Drive the 2″ x 2″ stake till the rod gives this reading when held up on it. The target may be set at once at the reading, if a target rod is used.

Use the same distance above grade for as long a run as practicable.

Use numbers that will reduce to simple terms in feet and inches.

Reduce the decimal of the rod reading to inches.

Mark the height in feet and inches of the top of the 2″ x 2″ stake above grade, on that stake, or on the witness stake beside it.

Do the same for each 2″ x 2″ stake at the time it is being set by the transient party.

Sometimes on a marsh all the grade stakes for a ditch can be set at the same height above grade. Do this where practicable, and give the workmen sticks cut to this height.

VIII. STAKING OUT A GRADE.

83. Information.

In grading, or paving, a street, stakes must be set as needed and not too many set at one time. Enough of them must be set to define the cross section of the street plainly for the workmen. This may mean as many as seven lines of grade stakes to be carried along the street.

In some street gutters four or five lines of grade stakes may be needed on a seemingly narrow strip of ground.

Grade stakes for curbs, either on streets or elsewhere, are troublesome to keep in place because they must be set close to the curb trench, and be used for line also. Drive two long stakes a little back from the trench, if practicable, and securely nail to them a strip of wood pointing cross wise of the curb and extending to its work edge, face, or corner. Make the end of the stick line and the bottom of it grade. Some times pieces of iron pipe 4 ft. long, or more, can be used for curb grades. Set the top to grade and the outer side parallel to line of curb.

Sidewalk grades in a built up district in a city oftentimes may be marked on watertables, stone steps, window sills, or by spikes or nails in the joints of brick work.

Grade stakes for concrete floors may be small and left in the concrete. They should be set as needed, with their tops to grade.

For grades for buildings, see IX.

IX. STRAIGHT LINE.

INFORMATION.

84. Rem. A straight line may be run by fore sights or by back and fore sights. By fore sights marks are set in line with the instrument point and another before it. By back and fore sights marks are set in line with the instrument point and another back of it. This last is much the better way and is the one commonly used.

The plate must be level. Keep sharp watch of the plate level parallel to the transit axis.

85. By Fore Sights. Set up the transit over a mark on the line. Set the line of sight on a mark on the line in the direction in which the line is to go. Give line for a mark, as a nail in a plug, beyond the sight mark where it can be seen from the sight mark. While the plug is being driven see if the point of the plumb bob hangs to the mark beneath the transit, see if the plate levels read level, and see if the line of sight strikes the sight mark. Correct the setting of the transit in any, or all, of these particulars, and be ready to give line as soon as the plug is driven. With one more look at the plate level parallel to the transit axis and to see that the line of sight strikes the sight mark, give line for a mark on the plug. See if the line of sight strikes the sight mark. If not, repeat these operations until it will. Give the signal "All right." Release the spindle clamp. Reverse the transit on its spindle. Level it if needed. Set the line of sight upon the sight mark. Locate a second mark beside the first with the same tests. Drive a small nail equidistant from the two marks located. The nail will be on the line.

Set up the transit over the sight mark. Use the new mark as a sight mark, and continue the line as before.

86. By Back and Fore Sights. Set up the transit over a mark on the line. Set the line of sight on a mark on the line in the direction opposite to that in which the line is to go. Reverse the telescope on the transit axis and give line for a mark in advance, as a nail in a plug. While the plug is being driven, see that the point of the plumb bob hangs to the mark under the transit, see if the plate levels read level, and reverse the telescope on the transit axis and see if the line of sight strikes the back sight mark. Correct the setting of the transit in any, or all, of these particulars, and be ready to give line as soon as the plug is driven. With one more look at the plate level parallel to the transit axis and to see that the line of sight strikes the back sight mark, reverse the telescope on the transit axis and give line for a mark on the plug. Reverse the telescope on the transit axis. See if the line of sight strikes the back sight mark. If not, repeat these operations until it will. Give the signal "All right." Release the spindle clamp. Reverse the transit on its spindle. Level it if needed. Reverse the telescope on the transit axis. Set the line of sight on the back sight mark. Reverse the telescope on the transit axis and locate a second mark beside the first, with the same tests. Drive a small nail equidistant from the two marks located. The nail will be on the line.

Set up the transit at the new mark. Use the one where it stood for a back sight mark and continue the line as before.

If the two marks located by either of these methods, as above directed are not at the same distance from the transit, the nail must be driven midway between them. By doing this the first two marks may be at some distance apart along the line, and in case the second mark comes off of the plug set to receive them, a stake may be driven to receive it far enough back, or forward, of the plug, to admit another plug between, without disturbing either, and the nail be driven therein. This will sometimes save considerable time.

If the transit is considerably out of adjustment it may take a wide plug to receive both of the first marks.

If the second of the first two marks comes off of the plug but so close to it that the nail will come on the plug, shove a stout peg into the ground beside the plug, to receive the second mark. This saves time.

87. **Rem.** In running a straight line use pickets, or sight marks of some kind, for back sighting to. This is better than a line staff, held by a "Back flag man" and may save the services of such a person.

Where a short sight cannot be avoided use a nail, point of a plumb bob, a pencil point, or some similar small thing to sight to, either forward or backward. The nail and paper mark is a good one, only use a small nail.

When sights must be short and obstructions in the way use a plumb line, of suitable length and fineness to sight to. It may be held steady by sticking the line staff, or a long stake, in the ground obliquely, and grasping it high enough up with the hand holding the plumb line. By changing the inclination of the staff the bob may be held over a mark, or brought into line from the transit.

When running a straight line, set one pair of opposite leveling screws on the line. The other pair will then stand across the line, and in the best position for keeping the plate level tube parallel to the transit axis reading level. This level tube is the more important of the two, in this work. It should be closely watched and kept reading level. After using the leveling screws for this purpose the reference sight must be repeated.

IX. STRAIGHT LINE.

FIELD WORK.

88. **Outfit.**

Transit.
Line staff.
Axe. 6 plugs. 5 pickets. Nails.

Examine the articles as issued, or be liable for defects found upon their return.

89. Directions.

Select a place open to the sky, where a straight line can be run for from a half a mile to a mile, and all the pickets be seen from the last plug, as across a valley.

Set five or six plugs, not less than 500 ft. apart.

Use the Back and Fore Sight method.

If possible refer the line to some distant mark, or object, in the rear.

Set up the transit where it is proposed to place the first plug. Back sight to the distant mark.

Reverse the telescope on the transit axis and see if the line of sight ranges along the ground where it is proposed to lay out the line.

If not, shift the transit until it fits this range.

Drive the first plug and nail in it accordingly. Leave a picket there.

Set up the transit over this first nail.

Back sight to the distant mark, or place one 500 ft. or more, to the rear for this purpose.

Set the second plug and nail not less than 500 ft. ahead on line by the back and fore sight method. Leave a picket there.

Set up the picket behind the eyepiece, so it will stand firm.

Put the plumb bob in a pocket, and draw away the transit without disturbing the picket.

Set up the transit over the second nail.

Back sight to the picket at the first plug, and set a third plug and nail not less than 500 ft. ahead on line, as before. Leave a picket there.

Set up the picket at the second plug behind the eyepiece and move the transit to the third nail.

Set up the transit over the third nail.

Continue the line as before until five or six plugs and nails have been set in the manner indicated, always backsighting to the last picket even if all the others can be seen.

Set up the transit over the last nail.

Back sight to the most distant picket, or mark.

See how near, by estimation, the vertical cross wire comes to bisecting each picket in the order of their numbers, 1, 2, 3, 4, &c. Focus the objective sharply on each picket.

Record the distance, as estimated, that the line of sight strikes away from the line at each picket, showing whether it is to the right (R.) or left (L.) as the line was run.

See if the line of sight still strikes the most distant mark.

If not, repeat the observations till it will and correct the record to conform to the final result.

Release the spindle clamp.

Reverse the transit on its spindle.

Level the transit, if needed.

Set the line of sight on the most distant mark, and repeat the observations, as before.

Record the results of these observations beside those first obtained.

Calling deviations to the R. +, and those to the L. —, add with their signs the results of both observations at each picket, to get the actual deviation of the line of sight at each picket.

Record these final results, showing which is R. and which L., beside the other records for each picket.

This gives a demonstration of the trustworthiness of the method and the precision with which the whole work has been done.

IX. STAKING OUT A BUILDING.

INFORMATION.

90. Rem. A building of any considerable size, or of an irregular plan, can be more accurately, and cheaply, staked out with a transit and measuring set and a level and leveling rod, than in any other way. Besides the work will be more trustworthy.

Examine the plans critically for errors in dimensions,—all of the plans, not merely the foundation plan. See that the sum of the interior dimensions plus the thickness of walls equals the exterior dimensions, every where, and in every way, across every part of the building. Record, in full, the results of this examination in the note book, whether errors and omissions are found, or not. If errors, or omissions, are found report them and refuse to begin staking out until the errors are corrected, and all omissions supplied so all the dimensions can be fully verified.

Examine the elevations and sections for the location of all grades, such as sub foundations, footings, watertables, ground surfaces, or any other thing whose height must be known. See if the figures agree. Record, in full, the results of this examination. Report all defects, deficiencies, errors, or discrepancies, and refuse to begin staking out until they are all properly taken care of.

Ask for all needed explanations. On any important building all corrections, changes, additions, or explanations, should be given in writing, or be made on the plans. If this is not done, enter in the note book, at once, all such verbal information, with the date, and source, or authority.

Be particular not to begin staking out until all the plans, and such parts of the specifications as relate to the location, levels for, and dimensions of, the building are fully and completely understood. The specifications and plans should agree, or be made to agree, upon these matters.

Too frequently not enough care is taken to make certain regarding the matters above referred to.

Too frequently the engineer is asked to stake out a building in a "Rush." This he should refuse to do, unless he knows the plans and specifications thoroughly before hand, or is relieved of all responsibility for the results of his work by a written and signed release. An engineer should never forget that the word "Rush" stands for mistakes, blunders, trouble, and dissatisfaction, and act accordingly.

Some line on the building should be designated as the one to be staked out. In a masonry building this may be the

brick line, the face of the water table, the face of the foundation wall above ground, or any similar one. In a wooden building if may be the face of the foundation wall, the outside of the frame, or a similar one. There should be room enough on the line boards for laying off spaces for lines for every thing outside of the line staked out. Such are watertable, foundation walls, and footings. The same should be true on the inside of the building. There should be room for the thicknesses of walls, for footings and the like.

Some line on the building should be designated as the one for which the leveler will give the elevation. In a frame building this is commonly the top of the foundation wall. In a masonry building the top of the first floor joists is used, also the top of the water table, the top of the finished foundation wall, or some similar line. The builder can be accommodated in making this selection but there should be a record to show unmistakably what line was used, and its relation to other lines on the building.

IX. STAKING OUT A BUILDING.

FIELD WORK.

91. Outfit.

Transit.
Measuring set.
Line staff.
Axe. Short stakes. Nails, 3d, 8d, 10d, and 20d. Mason's line.
2″ x 4″ scantling. 7/8″ x 6″ or 8″ boards, surfaced and with one edge of each straight.
Carpenter's level. Hand saw. Sledge, maul, or stone hammer.
Shovel or spade. Pick axe, or grub hoe,—surveyor's style.
Level.

Leveling rod.
Axe. Pegs. Spikes.

Examine the articles as issued, or be liable for defects found upon their return.

92. Directions.

Mark all of the corners of the building by nails in short stakes driven in the ground till firm. Verify the measurements and angles till no more can be done to make sure all of the nails are correctly set.

Stretch a mason's line from nail to nail, taking a turn around each.

See if anything wrong can be found. If so, correct it. Repeat the work till no fault can be discovered.

Set 2″ x 4″ scantling, as stakes, in the ground, high enough, where practicable, to reach up to, or a little above, the elevation to be given with the level. They should be far enough back from the excavation so as to be in no danger from caving, but at about the same distance from the building. They should stand firm. Drive them with a sledge, or stone hammer. In some ground holes may have to be dug for them. There must be at least two, and may be three, or more, in a group. About a convex corner three or more stakes are set so that boards nailed to them will be about parallel to the faces of the walls meeting there. Similarly for a reentrant corner. No stakes should be set within the limits of the excavation, as a rule. Stakes may be set to hold a board about at right angles with a wall to receive the line for that wall on its projection beyond the stakes.

Nail boards diagonally from near the top of one stake to where another goes in the ground. Tie the stakes together securely, in this manner.

With the level and rod mark, on at least one stake in a group, the elevation of the reference line for the levels for the building, as the top of the foundation wall, the top of the water table, or the top of the first floor joists, or whatever line is used. Check these levels fully.

Find, or make, a good B. M. to which the levels for the building are referred. Have this B. M. entirely outside of the work where by no possibility it can be disturbed. Connect this B. M. with another B. M. entirely away from the locality. Record all of these matters.

Nail the straight edge of a board to the level mark on a stake, straight edge up, and set this edge level with the carpenter's level. Nail the board to another stake, and complete the nailing with four nails in a stake. Thus do every where. Saw off the tops of the stakes even with the tops of the boards.

Transfer the lines of the building with the transit from the nails in the short stakes in the ground to the top edges of these boards.

Make a slight cut with the saw across the top of the boards at the line marks, only just deep enough to take a mason's line.

While transferring the lines to the boards, extend one, or more, of these lines each way of the building to distant marks that cannot be disturbed, for future reference. Measure carefully from the nails in the stakes first set on any line, each way to these reference marks on that line. Witnesses for the corner marks of the building, accurately measured, may also be used. Record all these matters fully, so the position of the building on the ground, or any line of it, can be quickly replaced.

With a rule draw out a witness mark from each saw cut on the surfaced side of the line boards and plainly write thereon a brief designation of what line of the building the saw cut is on, as "Brick Line."

Look over the tops of all the line boards and see if they are all in the same plane.

Stretch a mason's line in the saw cuts for every line of the building they mark.

Look over these lines with the utmost care for any mistakes, or faults, of any kind. They should all lie in the same plane. Measurements anywhere between them should agree with the plans.

Having done evedything that can be thought of to insure the correctness and security of the work, including good records of everything whatever, the building must be left for others. If the sills of a wooden building go on the finished foundation walls and fit, or the first course of cut stone work in a masonry building goes on and fits, the anxiety of the engineer should leave him.

IX. STAKING OUT A BUILDING.

INFORMATION.

93. Rem. On small buildings, projections which are rectangular, polygonal, or circular, and of no great size may be conveniently laid out by templates, it being necessary only to mark the points where the templates join the main structure.

Circular, or polygonal, forms of considerable size may be sometimes laid out by marking their centers within the limits of the excavation and marking the points where they join the rest of the structure. Such centers should be marked in a most substantial manner. An old boiler flue, or piece of 2″ or 3″ iron pipe, may be driven plumb, the top to the proper elevation, and a plug put in the top on which the center may be marked, and closely witnessed by measurements to other marks as references. Even this may not answer in some cases.

Large, and especially irregular buildings may be laid out by coördinates. This is a satisfactory way because of the numerous checks it furnishes, and they are needed. Select convenient axes of reference. These may be lines of the building itself, or frequently one of them may. In place of axes of coördinates the building may be surrounded by a rectangle that can be laid out on the ground, and points on the plan referred to the sides of this rectangle,—really coördinates. Number all the points on the plan that are to

be marked on the ground. Select the principal axis of reference, anywhere across the building in any convenient direction, or entirely without it, and also the origin of coördinates, or measurements, on this line. Record these facts. From the plans compute and fully verify, beyond a question, the coördinates of every point thereon which is to be laid out. Record the numbers of all of these points with their coördinates against those numbers. Lay out the principal axis of reference on the ground and mark the origin of measurement. Measure off on this line the coördinate along that line of each point of the plan and mark the measurement by a nail in a stake in succession, and lay out a line at right angles with the principal axis. On this line measure the other coördinate of the designated point and mark that point by a small nail in a stake numbered for it. Measure between these nails along the lines of the building. Record the results, and compare them with corresponding dimensions on the plan. They should agree with the plan. This gives one, or more, checks on every line. This method can be used with success to keep a building on a lot barely large enough to receive it, without staking out much, if any, of it.

In the simpler structures the work may be verified as follows Lay out the controlling angle, or angles, with the transit Locate the various marks by measurement. Use the transit to test the angles thus obtained. Or, lay out various lines with the transit and locate marks thereon by measurements. Verify the work by measuring closing distances between the marks set in this manner, the same as if the points had been laid out by coördinates, as above outlined

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DO ANY OF THESE THINGS FIT YOU?

Stop !

Going out to work without a note book and pencil.

Stop !

Going out to work without all the information to be had.

Stop !

Taking instruments out to work without first knowing their condition.

Stop !

Taking instruments out to work without all necessary accessories,—as tripod, plumb bob, reading glass, shade, or adjusting pin.

Stop !

Sighting at the top of a line staff, or station pole.

Stop !

Plumbing up with a line staff. Use a plumb bob and line.

Stop !

Using splinters, and twigs, to mark stations with. Use stakes, or plugs.

Stop !

Using stakes for plugs. Use plugs, four inches, or more, across, driven flush with the ground.

Stop !

Pulling up plugs till through with them.

Stop!

Leaving any stakes, plugs, or other marks, temporarily in use while making a survey, to be mistaken for the real marks the survey was made to obtain, or perpetuate. Knock out every thing else,—but not till done with them.

Stop!

Removing land marks, to plant others, except in the presence of witnesses, and with a complete record of every one present, and every thing found, done, and planted.

Stop!

Being so particular to read the leveling rod to thousandths where it is not needed, while misreading the tenths and feet. The thousandths do not really amount to so very much when the feet, or tenths, or both, are read wrong.

Stop!

Making hasty jots and calling it a record. Make a record to be read, understood, and not mistaken, by a stranger. Do it when the work recorded is done,—not leave it to be guessed at afterwards.

Stop!

Making scattered, confused, or mixed up notes. Use a form, or write in full.

Stop!

Using an instrument the instant any of its parts work hard. Find out what the matter is and fix it, or have it fixed.

Stop!

Leaving things around on the work, and forgetting them. This delays not only the careless person who forgets, but others,—perhaps stopping the whole work.

Stop!

Leaving things around at all,—to be picked up afterwards.

Stop!

Putting things away in any kind of disorder.

Stop!

Putting instruments, or tools, of any kind, away, unfit for immediate use.

Stop!

Depending on others to make good any careless practices. Strive to do things as well as they can be done.

Stop!

Doing things "Good enough." Do them so no man can better them.

Stop!

Trying to work without judgment,—endeavoring to mechanically follow a process. Strive to become able to make such things as processes. Processes, methods, learning, attainments, are properly tools, or servants,—not masters.

Stop!

Being satisfied with the atainments acquired in any direction. What has been accomplished is but a step stone to something more, or better.

EXAMINATIONS.

Outfit.

To write with ink.
Triangles.
Scale.
Pencil dividers.
Pencil eraser.
Pencil,—No. 3.

Write all of the subjects for examination, with their numbers, on the first leaf of the blue book.

Write with ink. Write plain,—or print.

Use well drawn diagrams.

No reports of examinations given out.

CONDITIONED STUDENTS.

To continue their work until able to write correctly on all of the subjects in the following list:

Measuring with steel tapes.

Reading an angle.

Traversing.

Setting up a transit and a level.

Peg levels.

Verniers.

Least reading.

Reading a vernier.

Profile leveling.

Running a straight line.

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